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Antchak et al.

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(45) **Date of Patent: Oct. 11, 2016**

(54) **INTELLIGENT BELT DRIVE SYSTEM AND METHOD**

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(21) Appl. No.: **14/342,985**

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(2), (4) Date: **Apr. 22, 2014**

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PCT Pub. Date: **Mar. 14, 2013**

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Related U.S. Application Data

(60) Provisional application No. 61/531,021, filed on Sep. 5, 2011, provisional application No. 61/584,314, filed on Jan. 9, 2012, provisional application No. 61/588,076, filed on Jan. 18, 2012.

(51) **Int. Cl.**
F16H 7/12 (2006.01)
F02B 67/06 (2006.01)

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(52) **U.S. Cl.**
CPC ***F16H 7/12*** (2013.01); ***B60K 25/02*** (2013.01); ***F02B 67/06*** (2013.01); ***F16H 7/1281*** (2013.01); *B60K 2025/022* (2013.01);

(Continued)

(58) **Field of Classification Search**
USPC 701/36–49; 474/100–138
See application file for complete search history.

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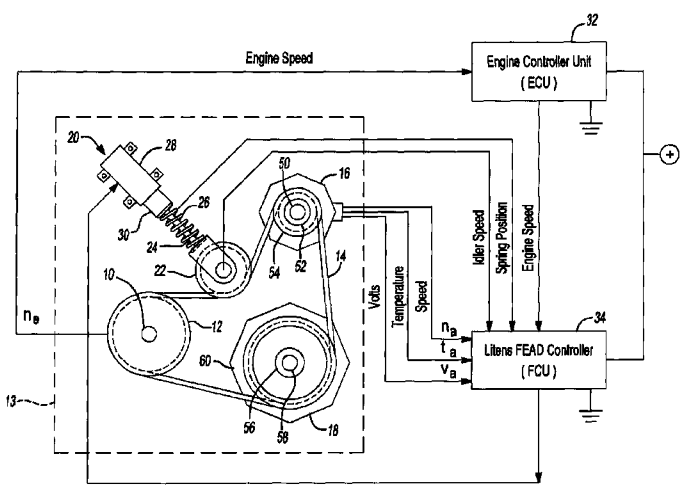
Assistant Examiner — Timothy Nesley
(74) *Attorney, Agent, or Firm* — Millman IP Inc.

(57) **ABSTRACT**

In the one aspect, a tensioner that incorporates a fluid actuated cylinder and that is capable of precognitively anticipating when is desirable to increase the tension in a belt or other endless drive element so as to prevent belt slip prior to events that would raise the risk of it.

20 Claims, 61 Drawing Sheets



(51) **Int. Cl.**
B60K 25/02 (2006.01)
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(52) **U.S. Cl.**
CPC *F16H 2007/081* (2013.01); *F16H 2007/0806* (2013.01); *F16H 2007/0823* (2013.01); *F16H 2007/0876* (2013.01); *F16H 2007/0882* (2013.01); *F16H 2007/0885* (2013.01); *F16H 2007/0891* (2013.01); *F16H 2007/0893* (2013.01); *F16H 2007/0897* (2013.01)

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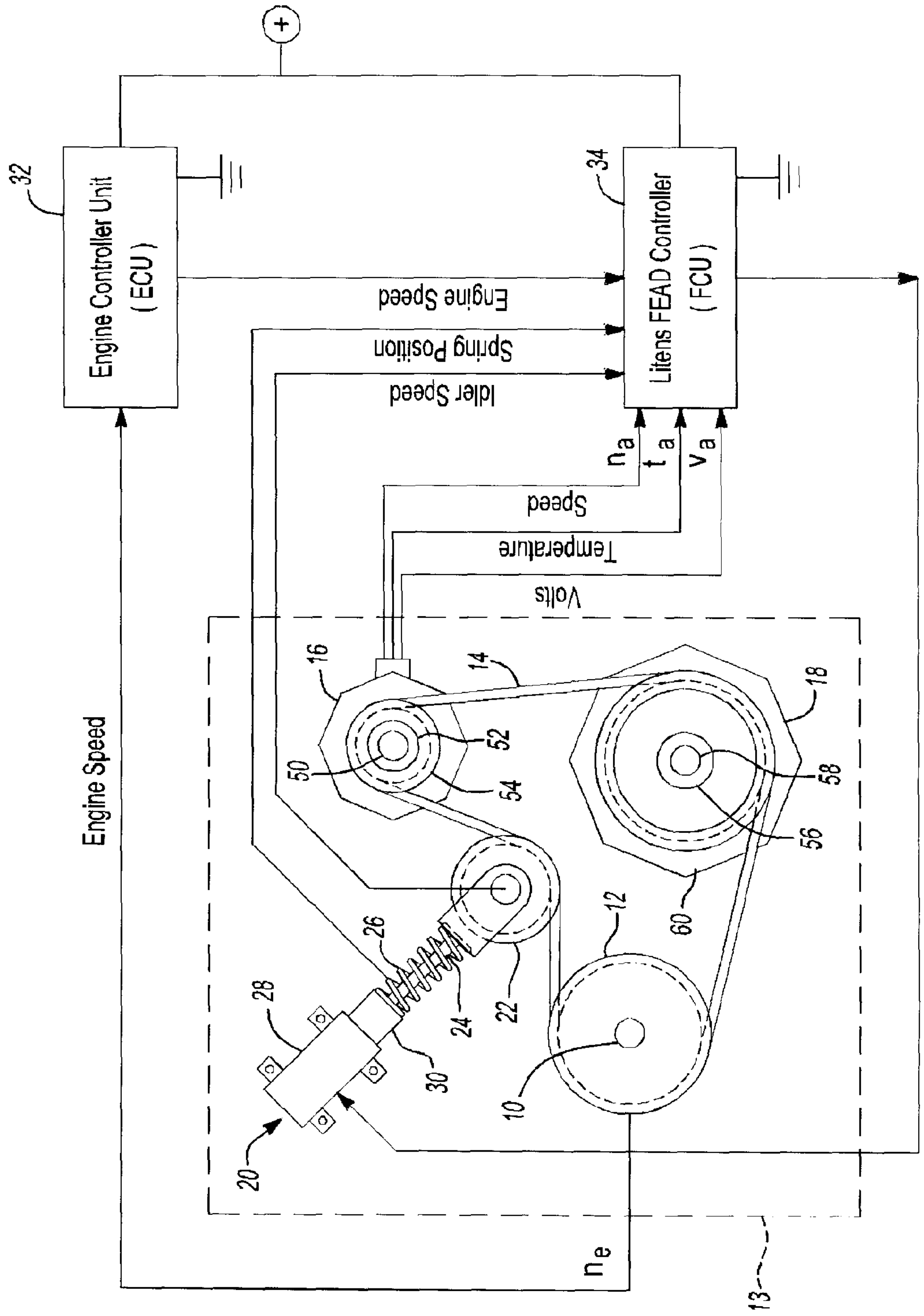
Engine Controller Unit
(ECU)
32
Litens FEAD Controller
(FCU)
34
Engine Speed
Spring Position
Idler Speed
Speed
Temperature
Volts
Engine Speed
n_a
t_a
v_a
n_e
10
12
13
14
16
18
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22
24
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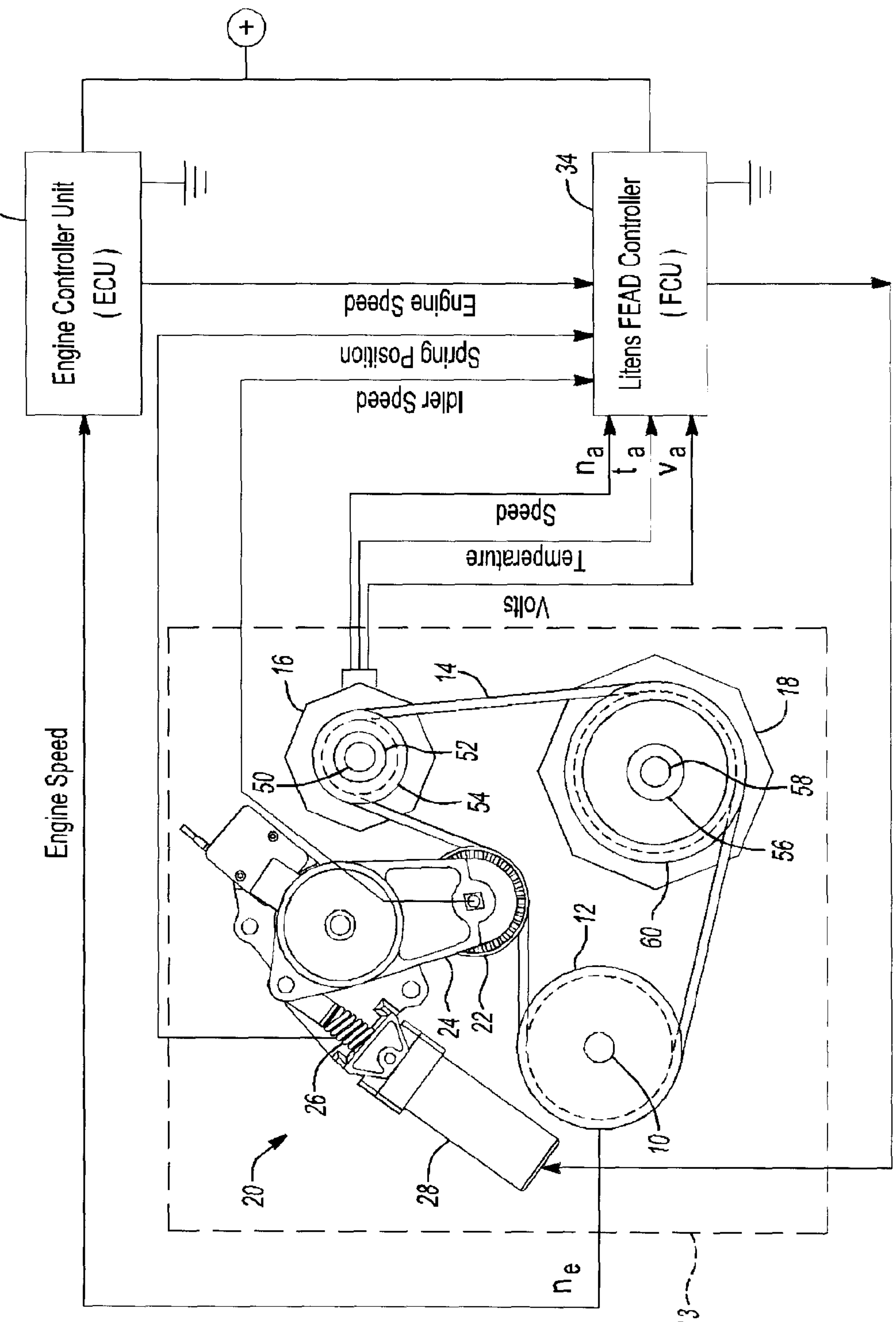
60

FIG. 1a



Engine Controller Unit (ECU)
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Litens FEAD Controller (FCU)
34
Engine Speed
Spring Position
Idler Speed
n_a
t_a
V_a
Speed
Temperature
Volts
Engine Speed
n_e
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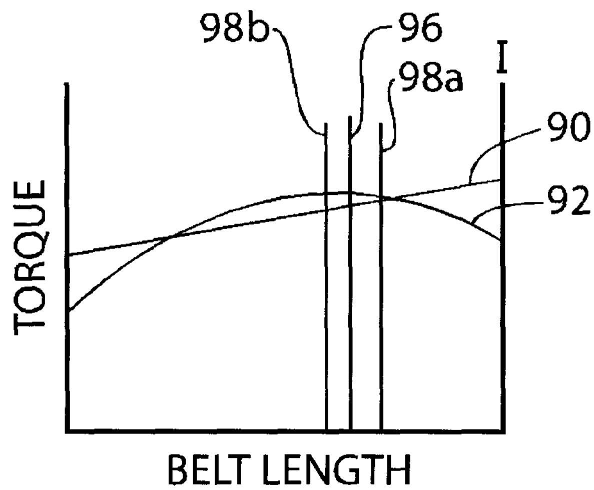
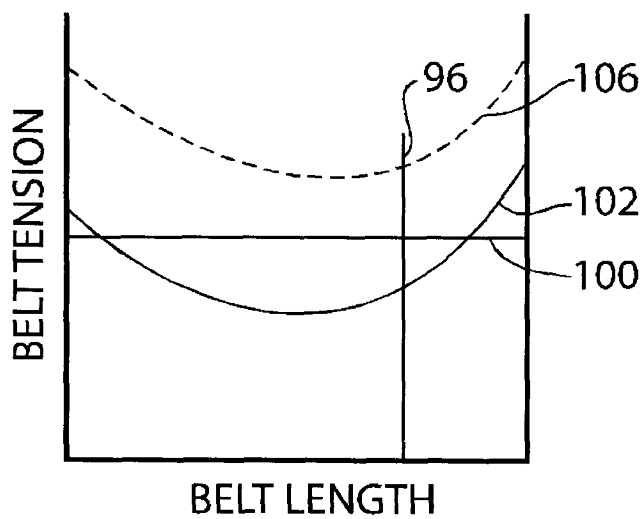
58
60

FIG. 1b



98b
96
98a
I
90
92
TORQUE
BELT LENGTH

FIG. 1c



96
106
102
100
BELT TENSION
BELT LENGTH

FIG. 1d

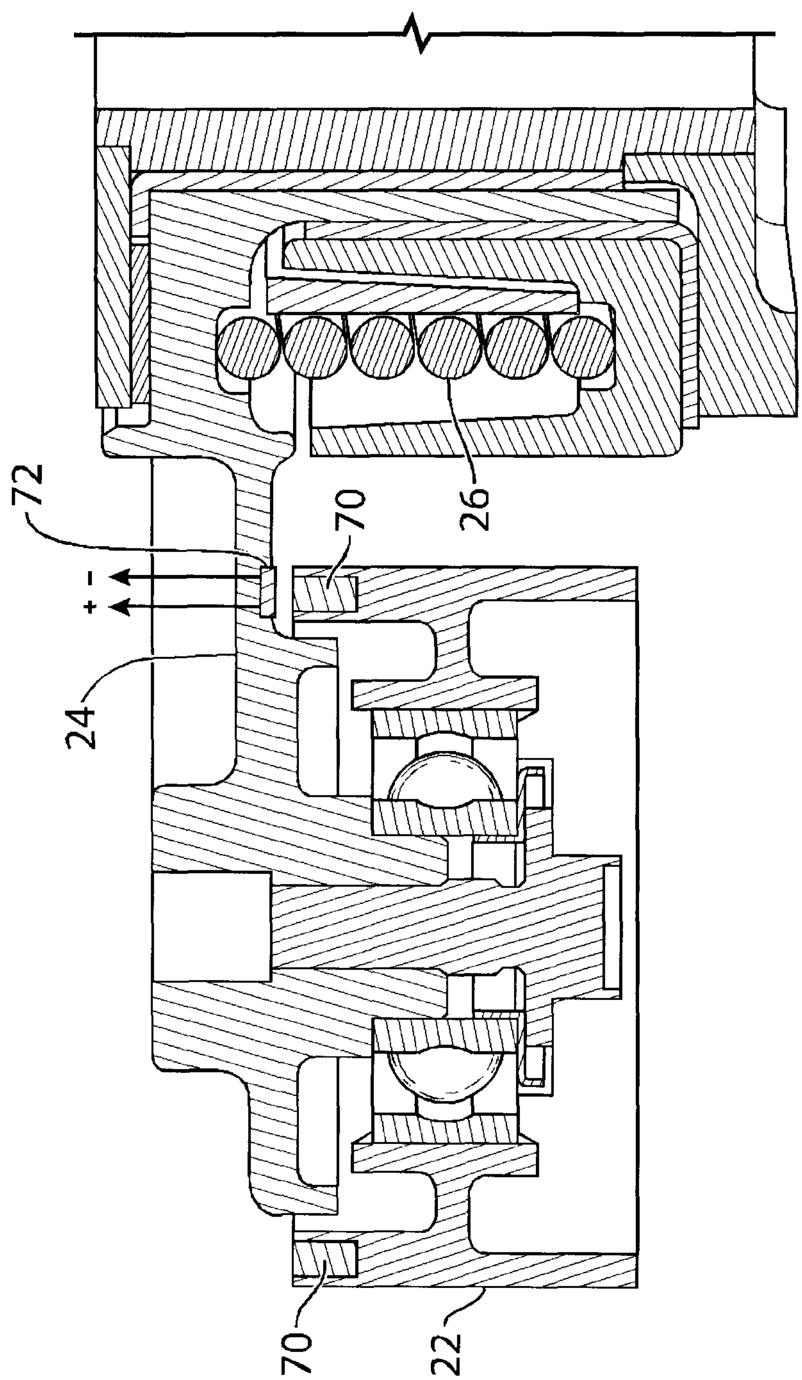


FIG. 2a

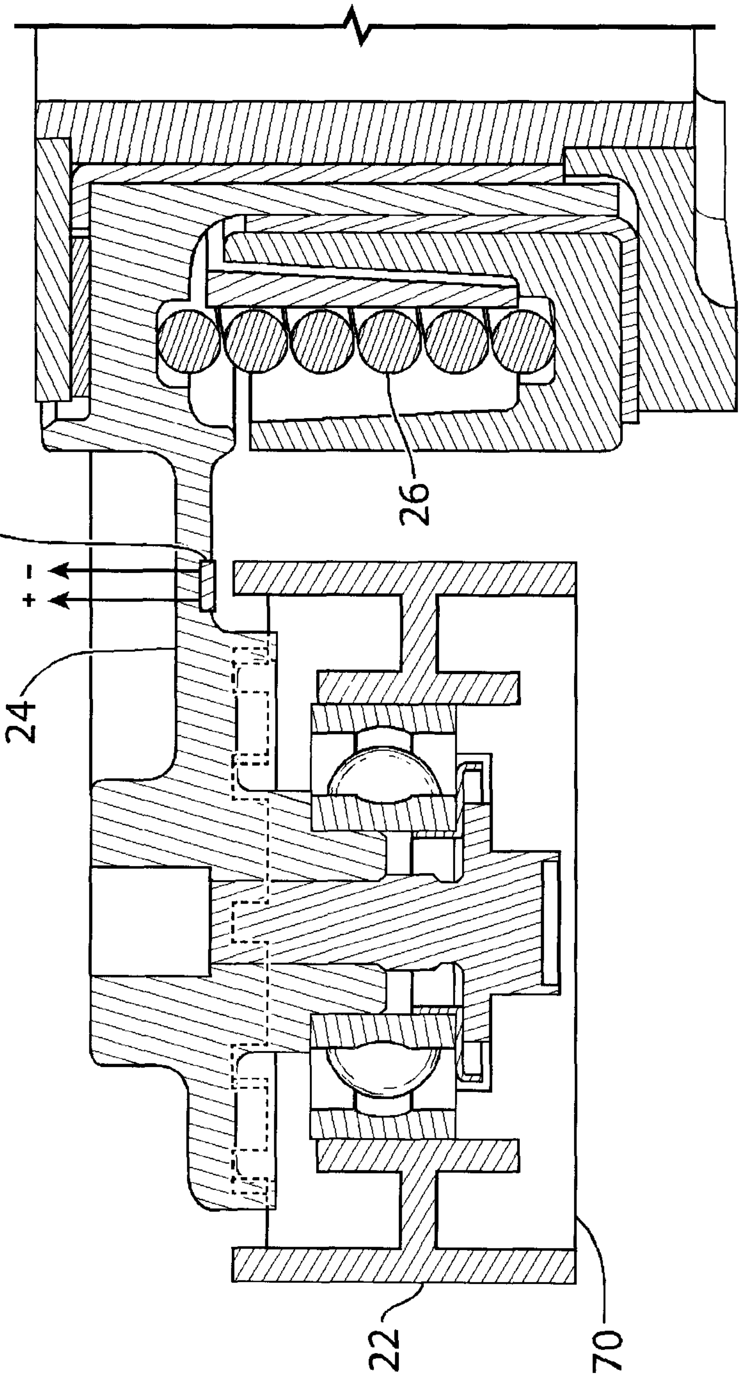


FIG. 2b

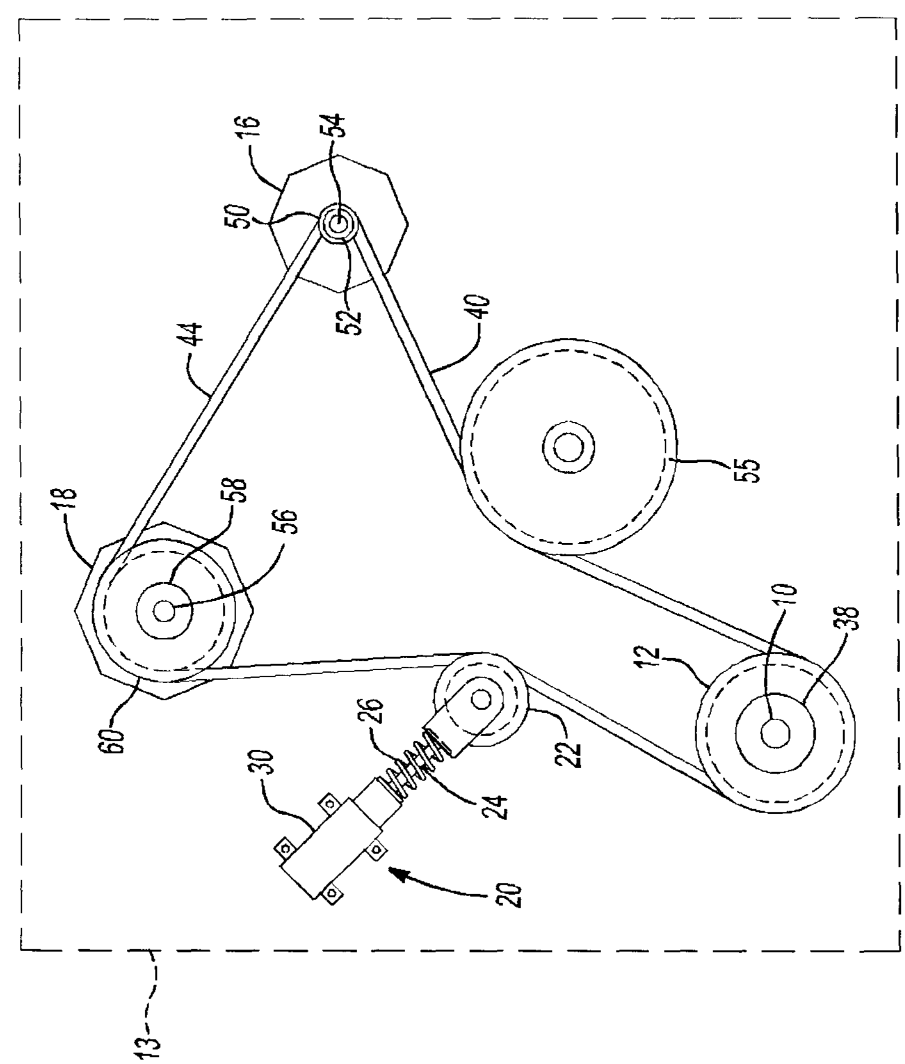
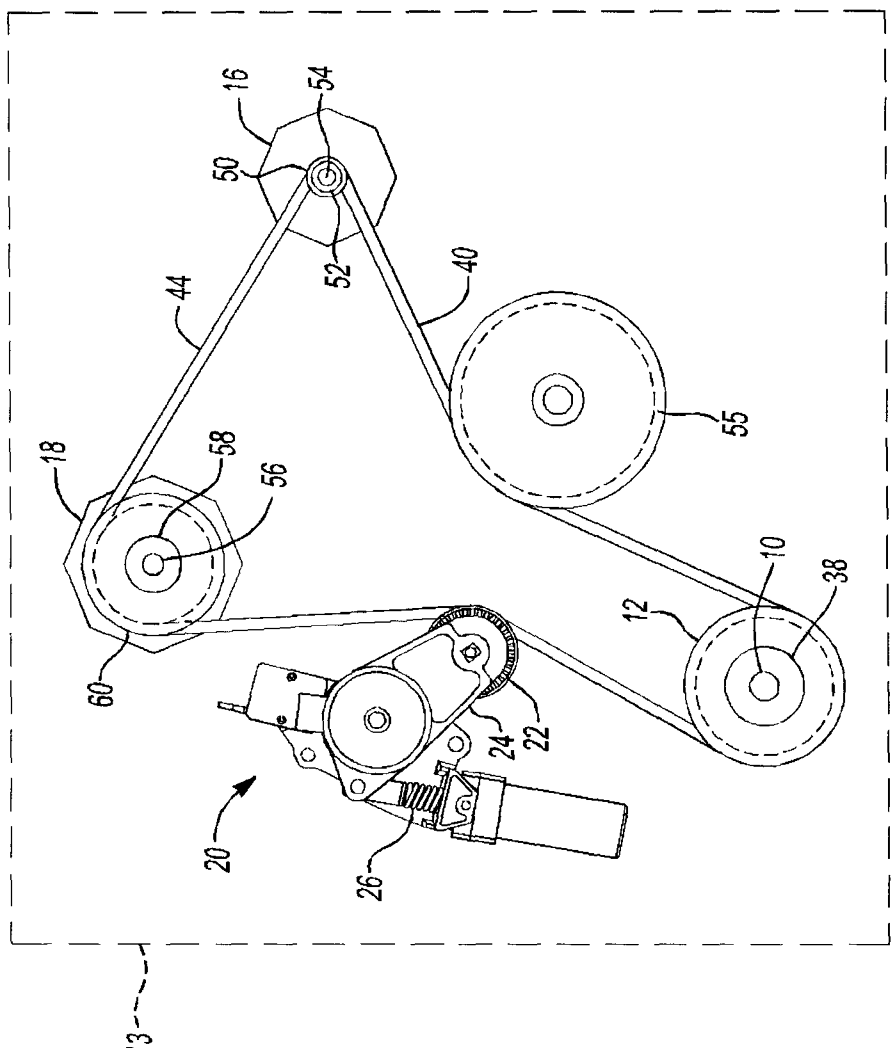


FIG. 3a

FIG. 3b



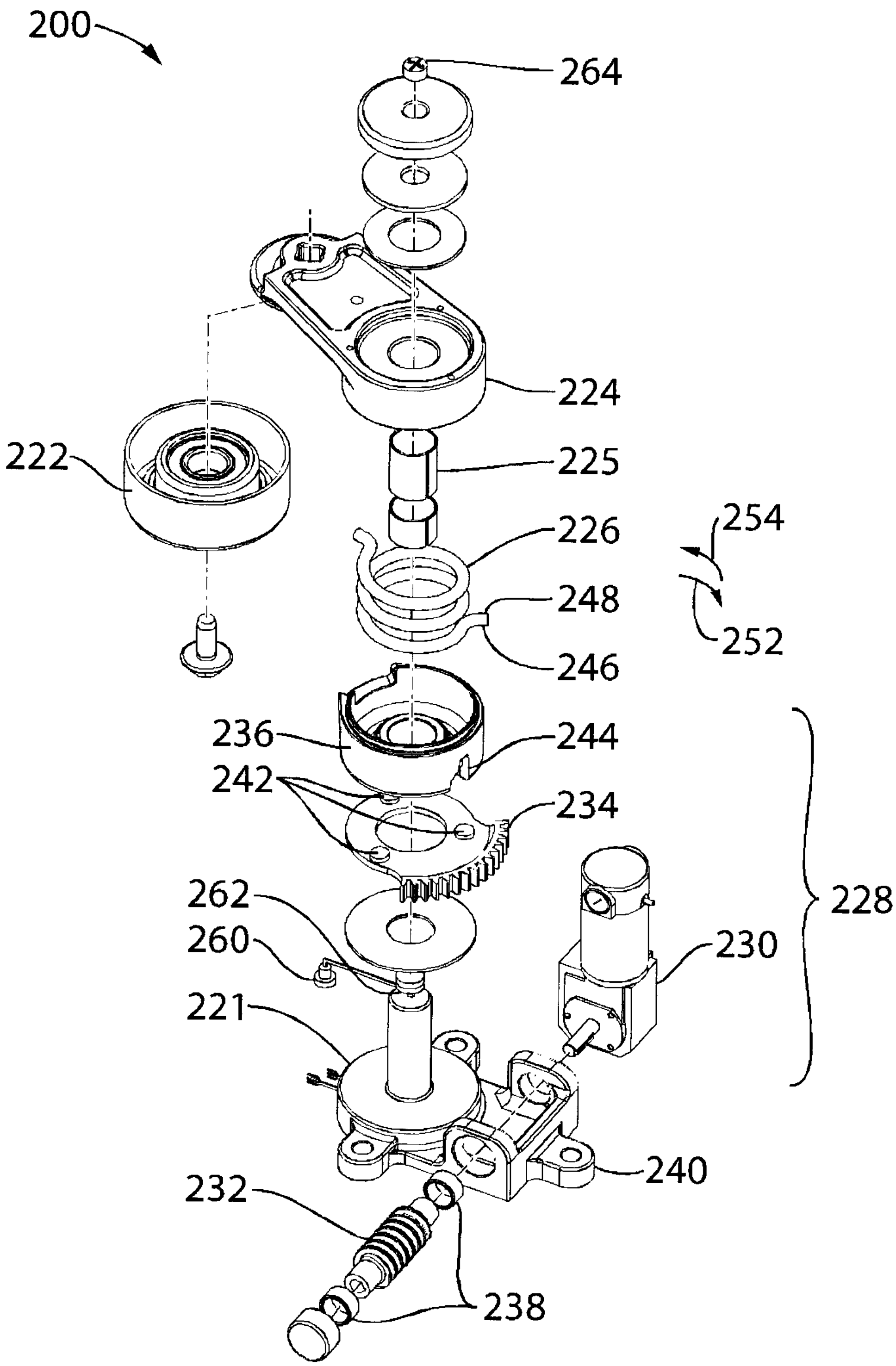

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FIG. 4a

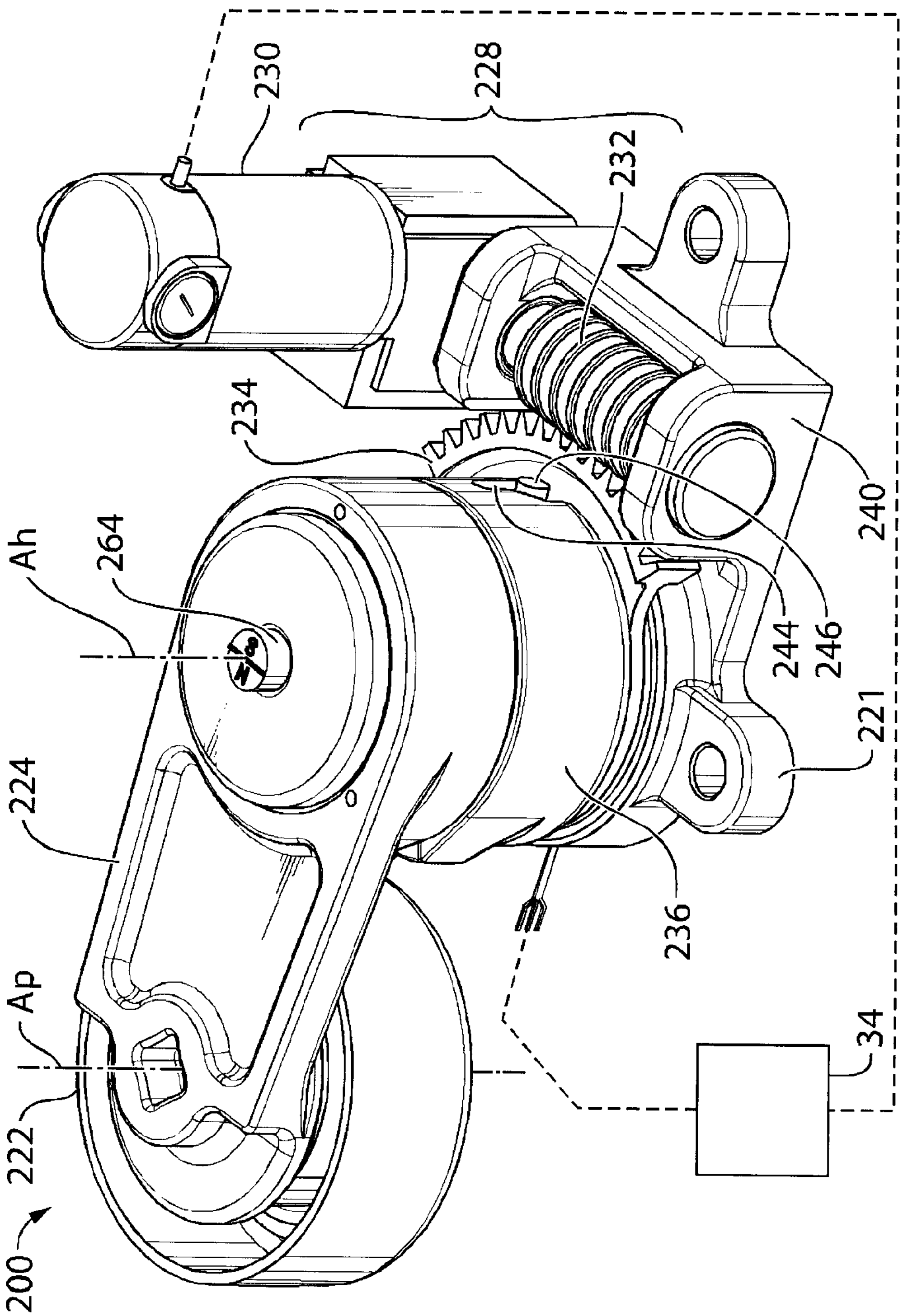


FIG. 4b

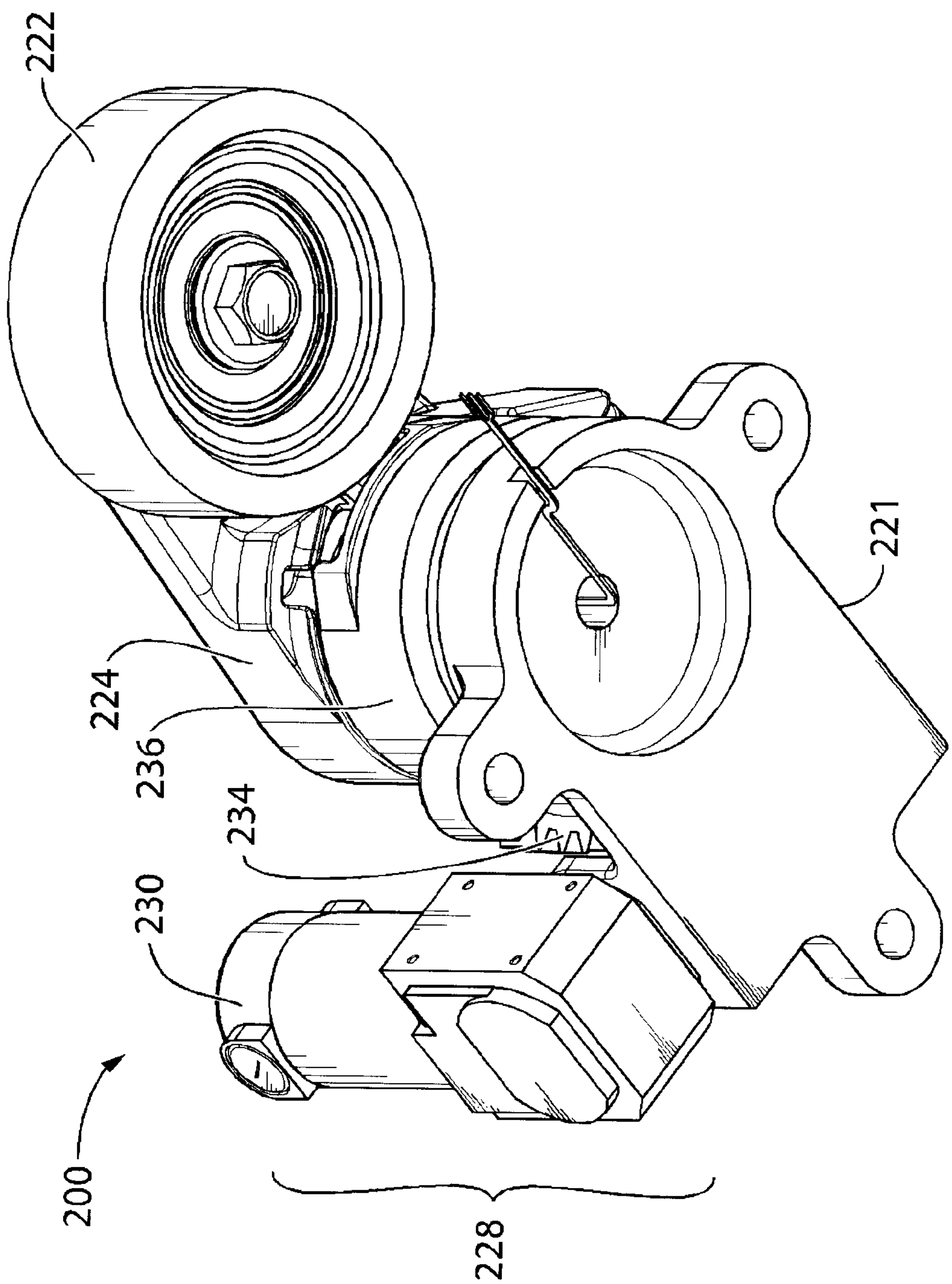


FIG. 4c

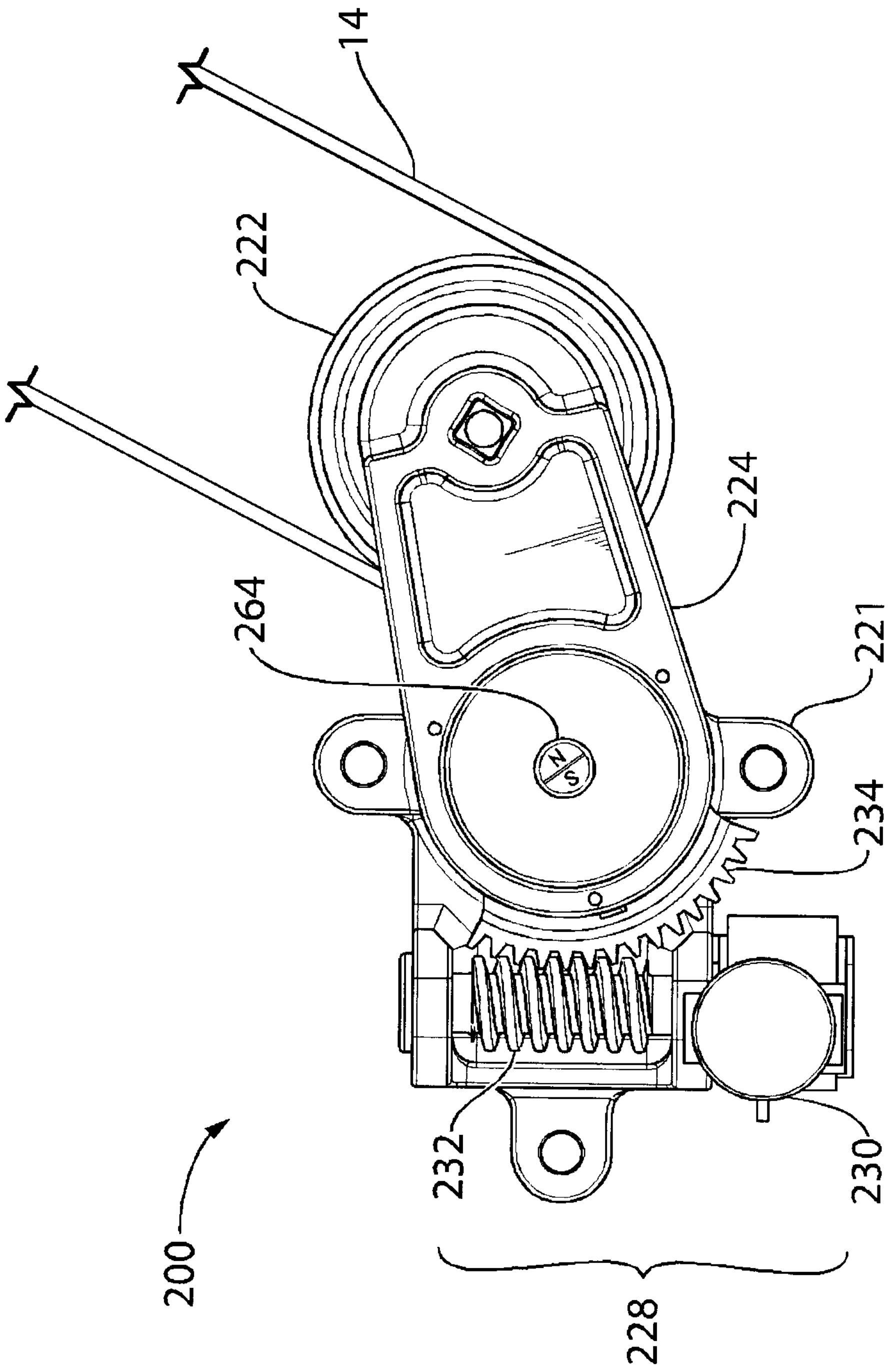


FIG. 5a

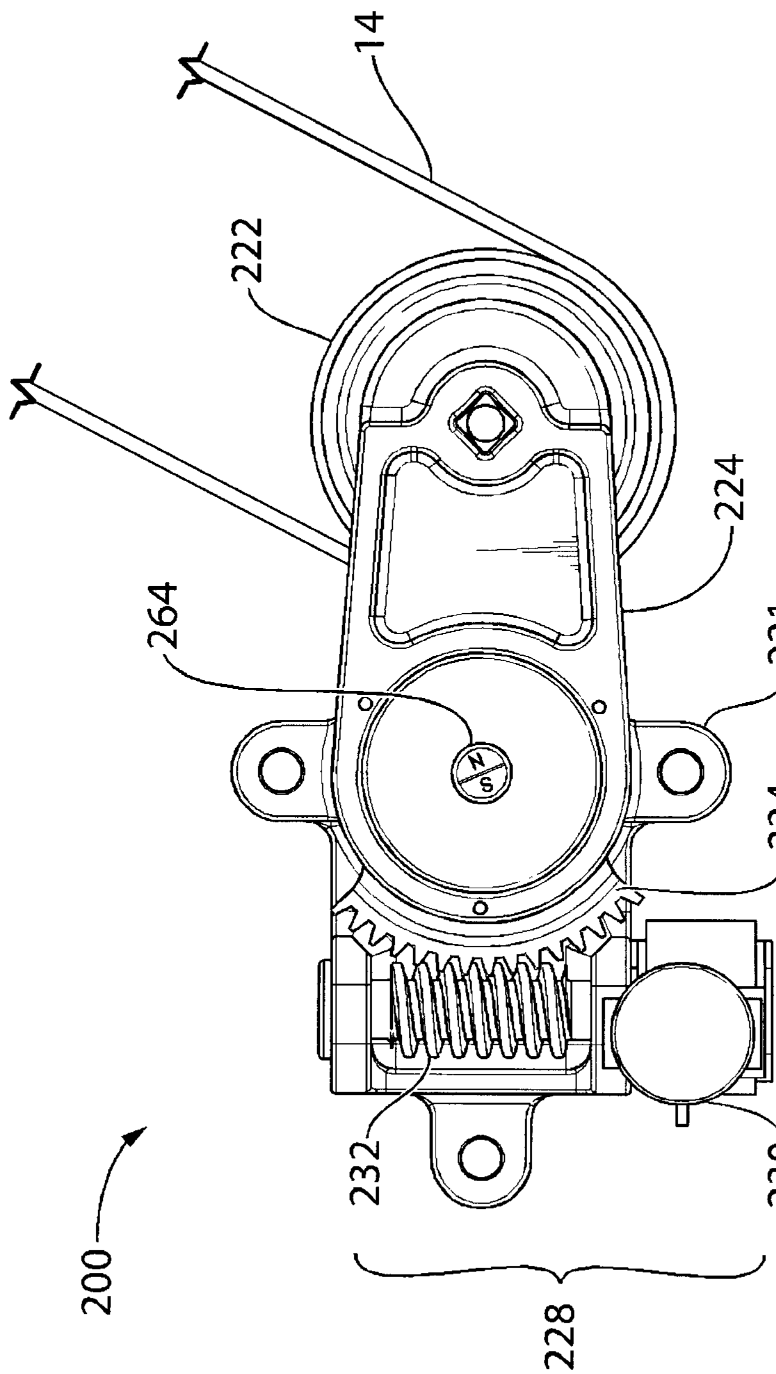


FIG. 5b

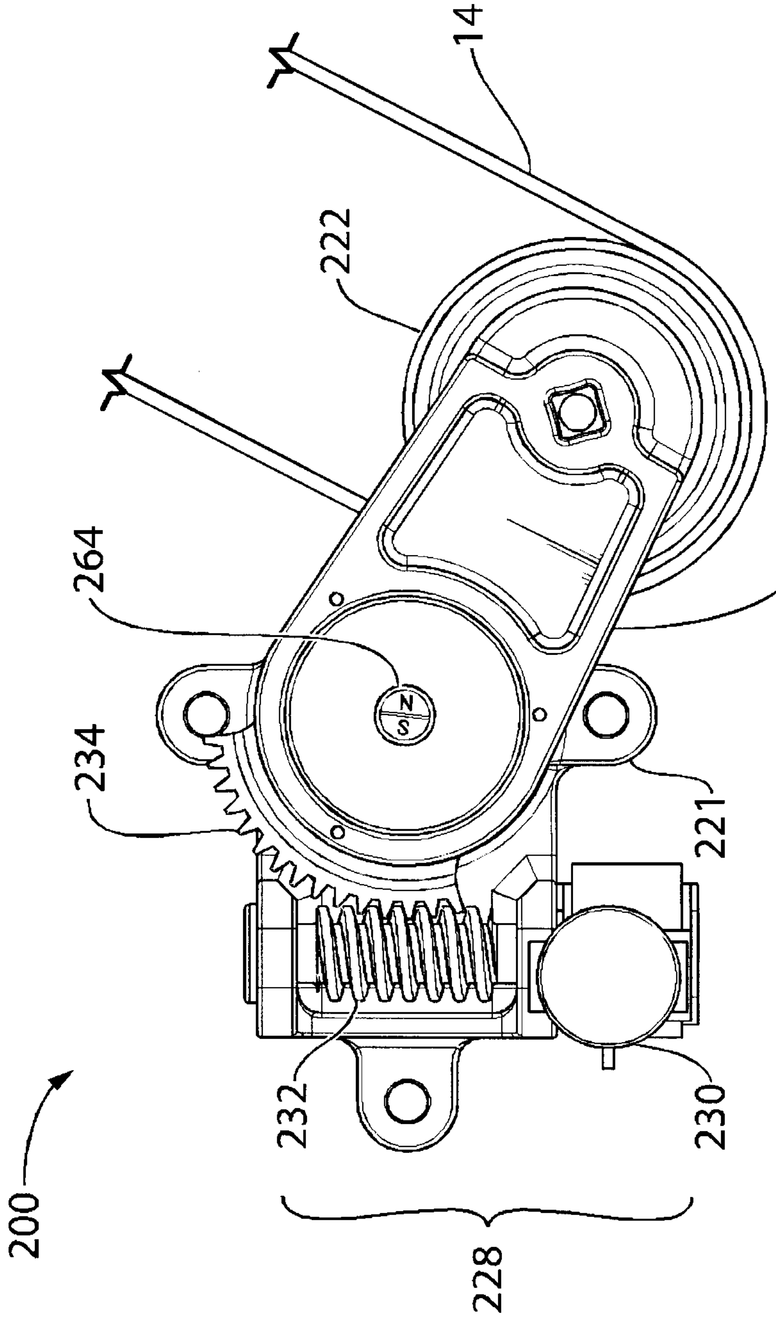


FIG. 5c

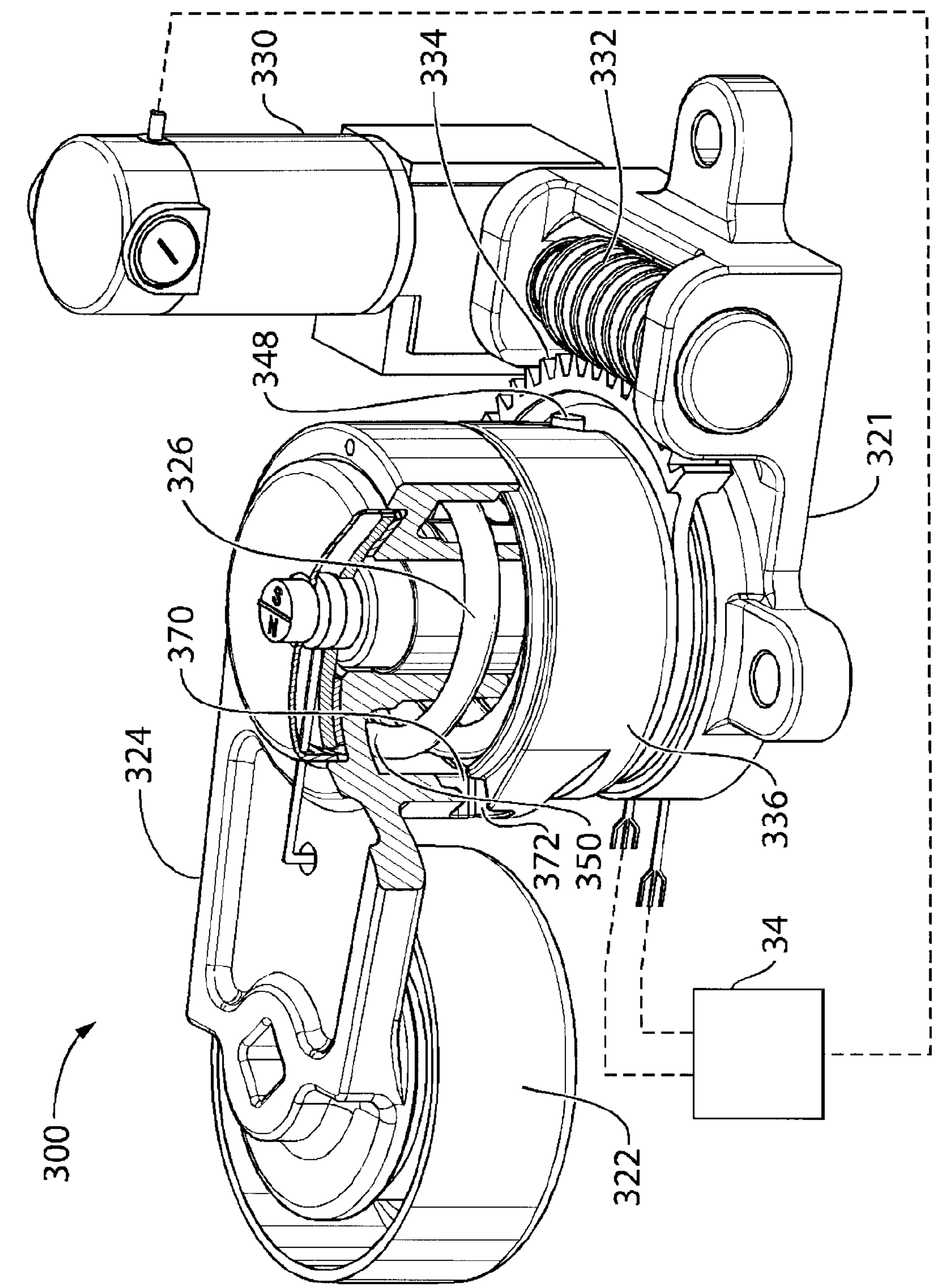


FIG. 6

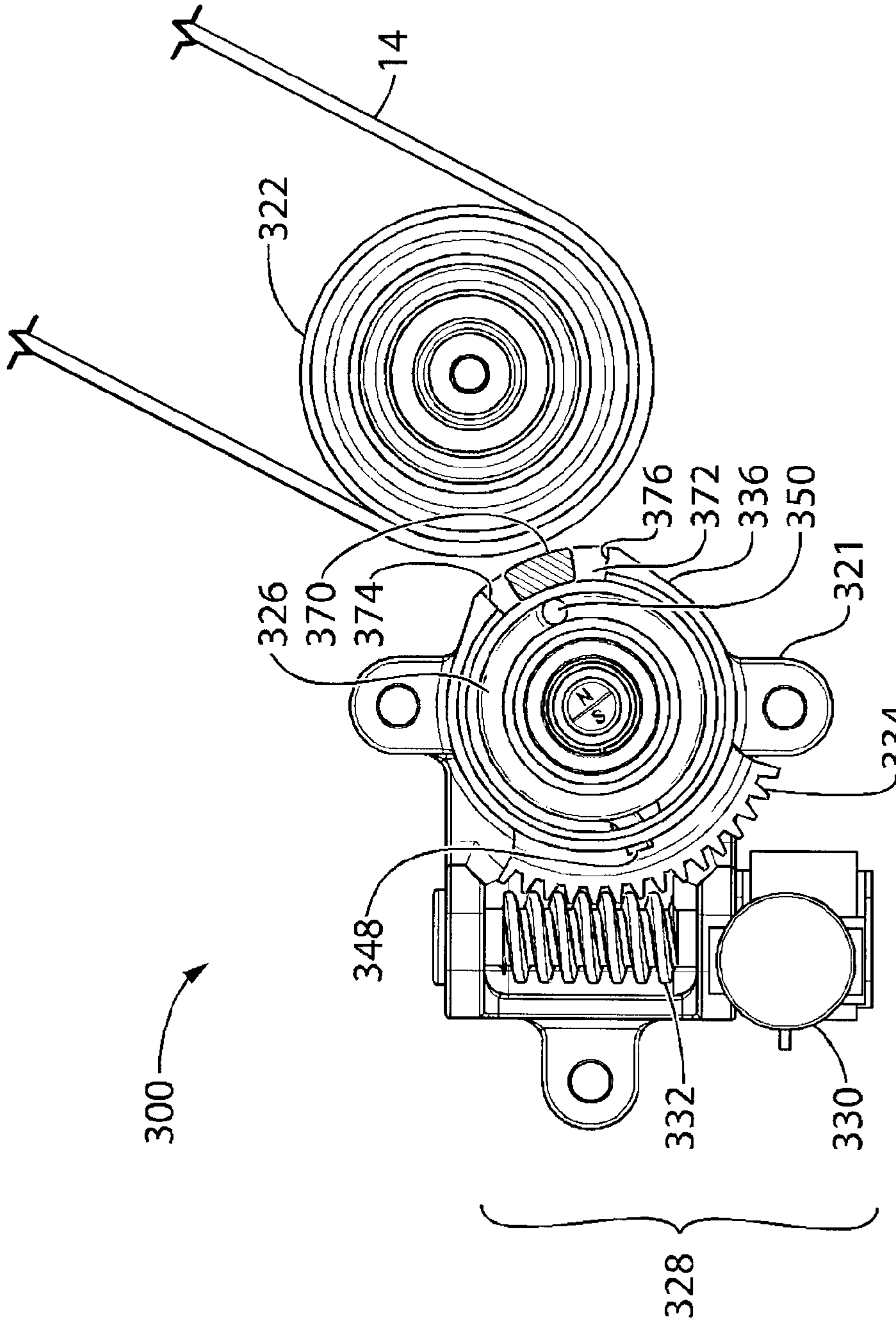
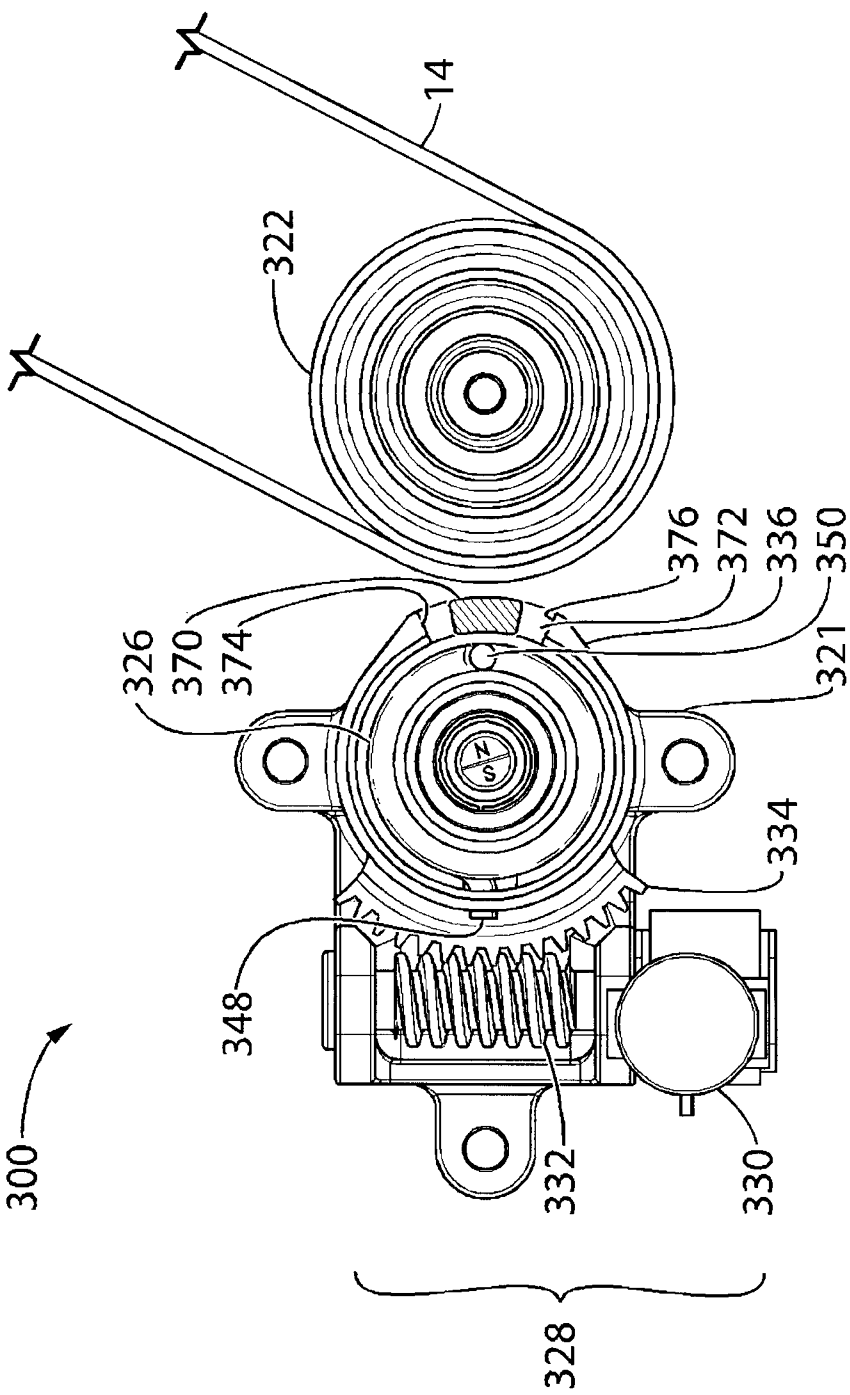


FIG. 7a

FIG.7b



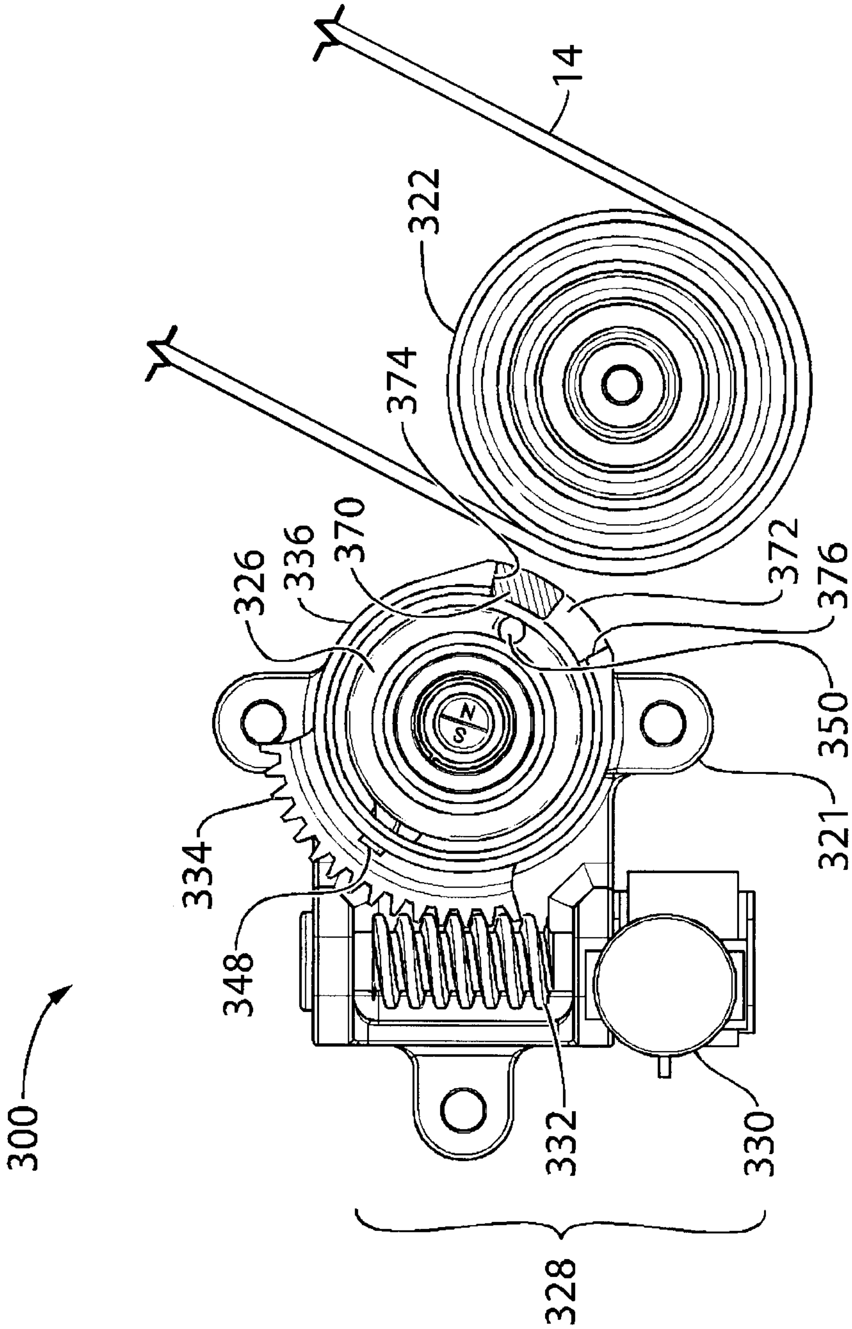


FIG.7c

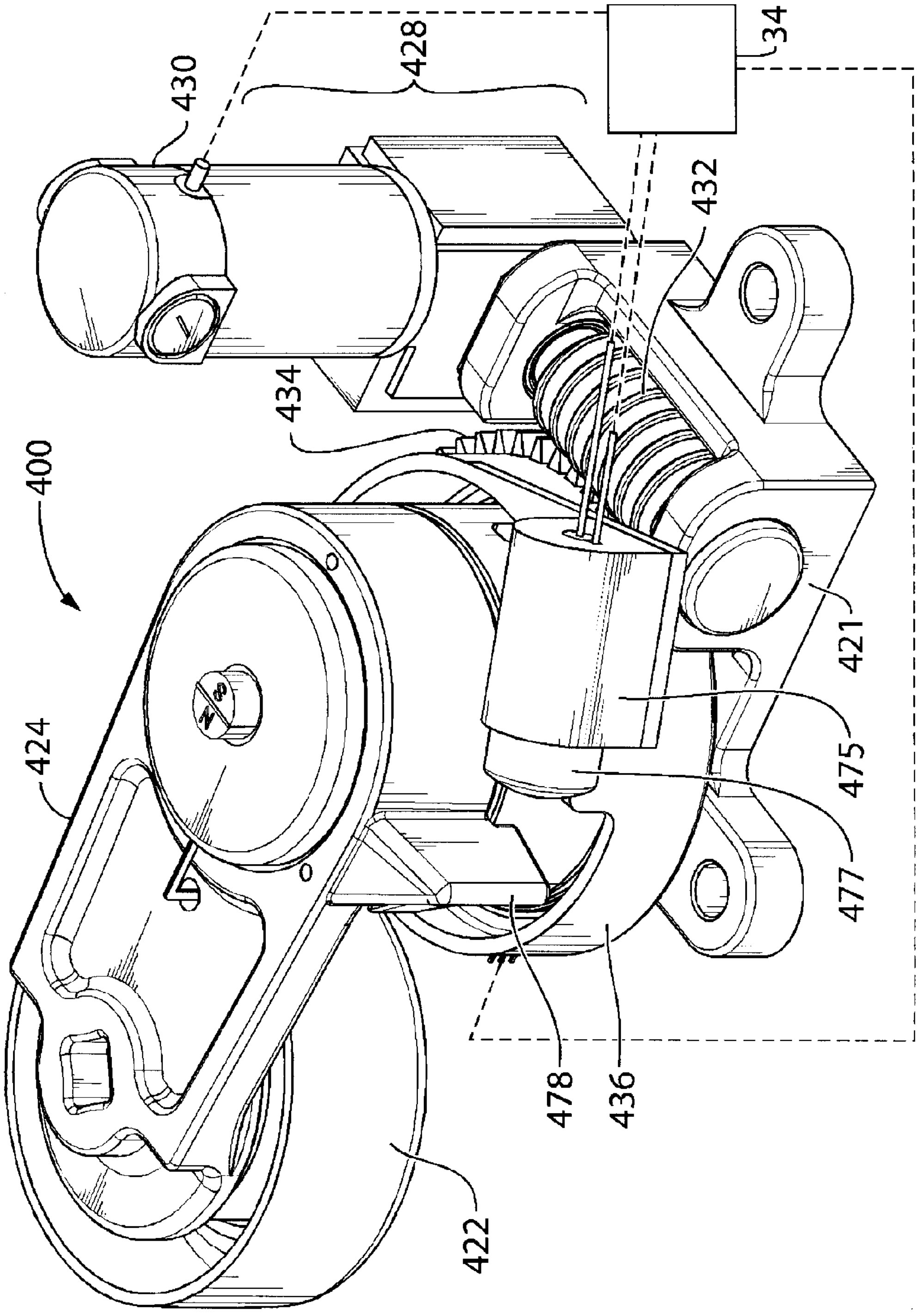


FIG.8a

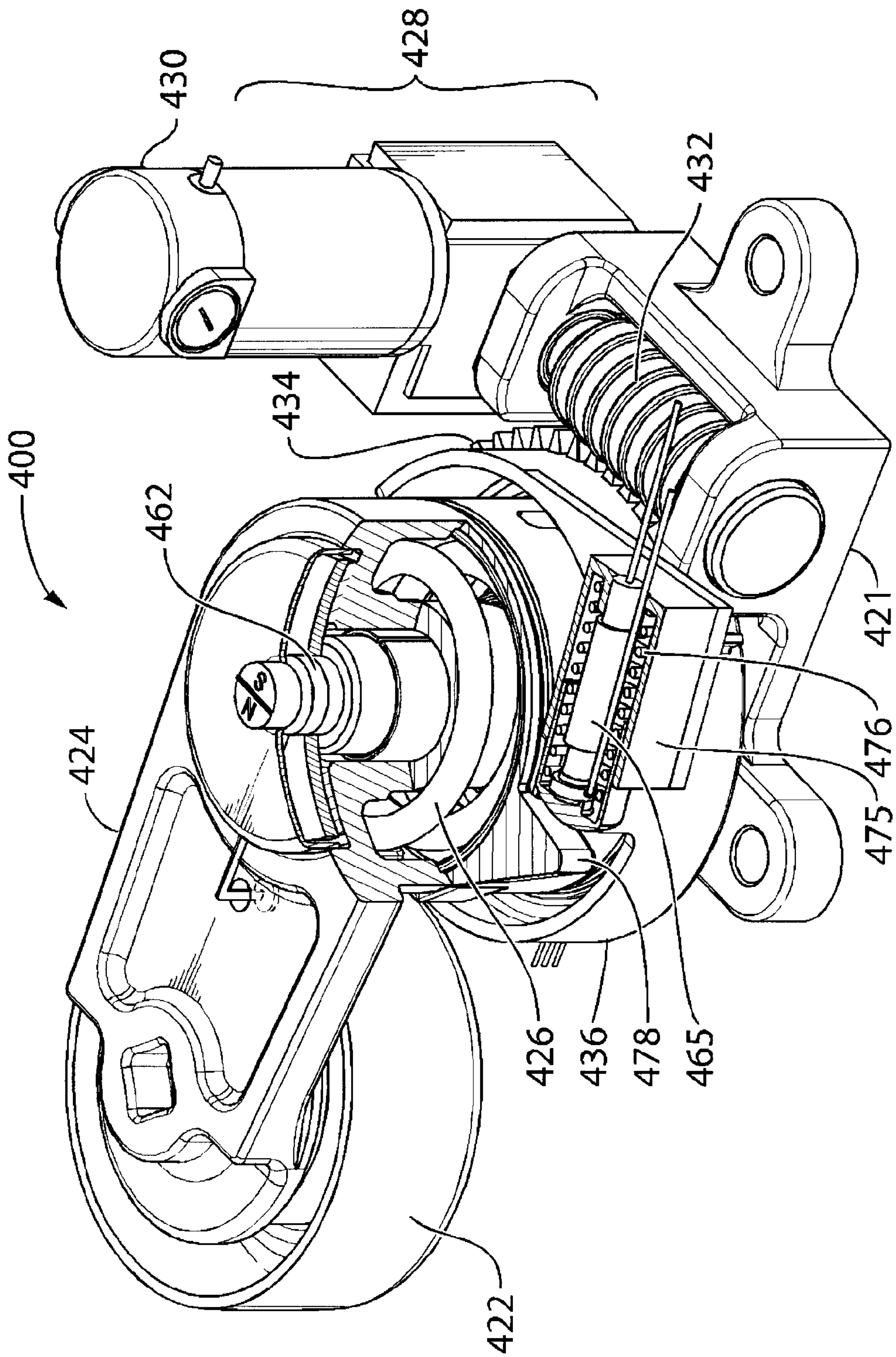
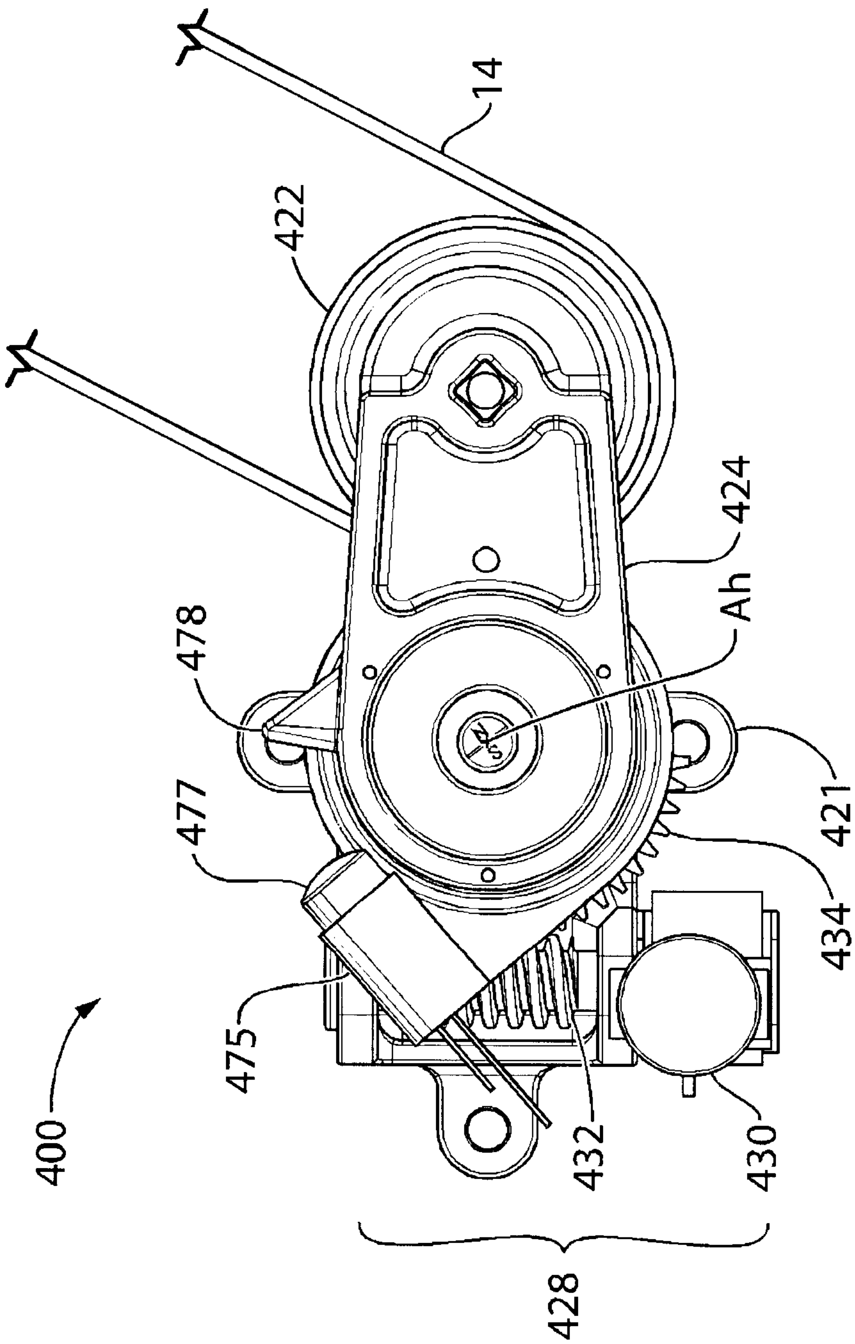


FIG. 8b

FIG.9a



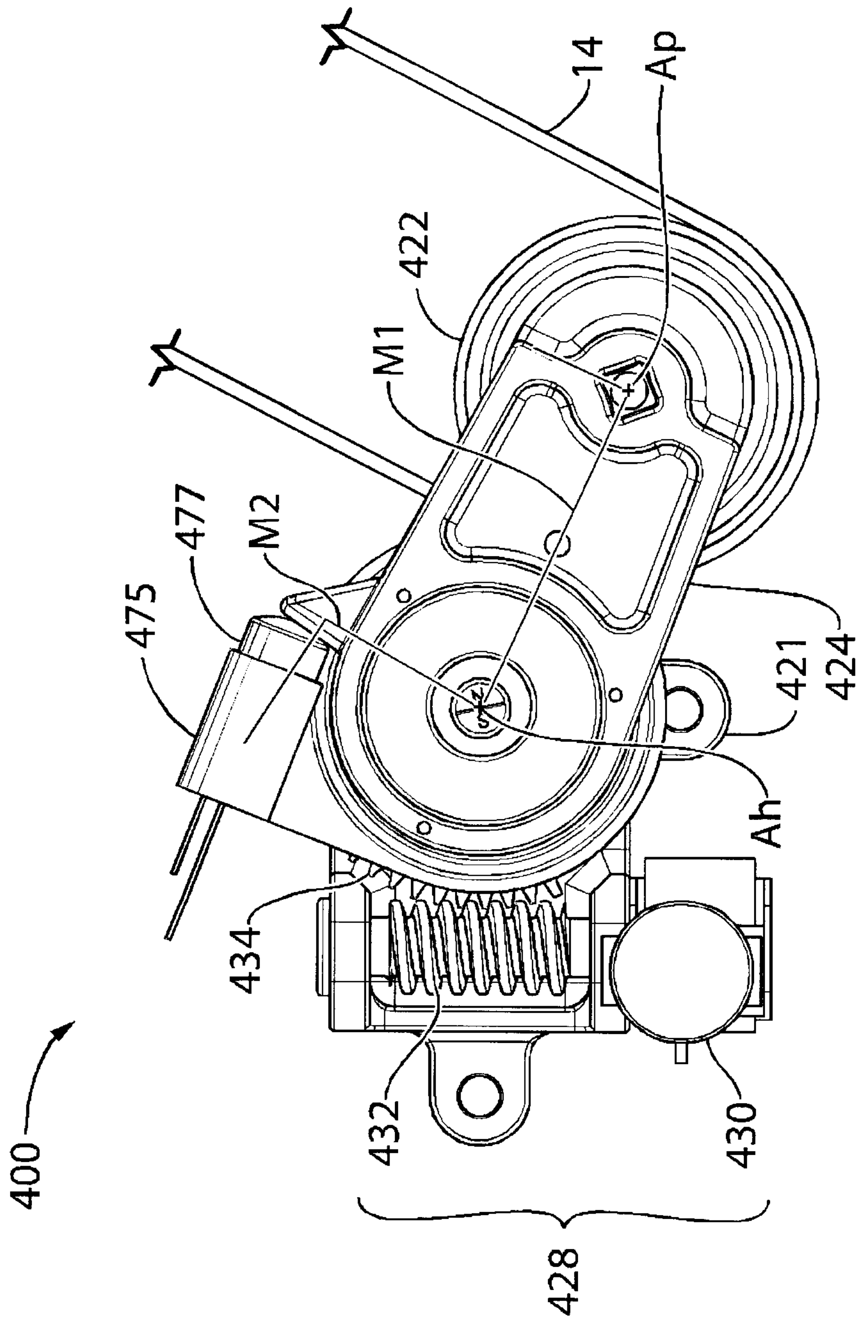


FIG.9b

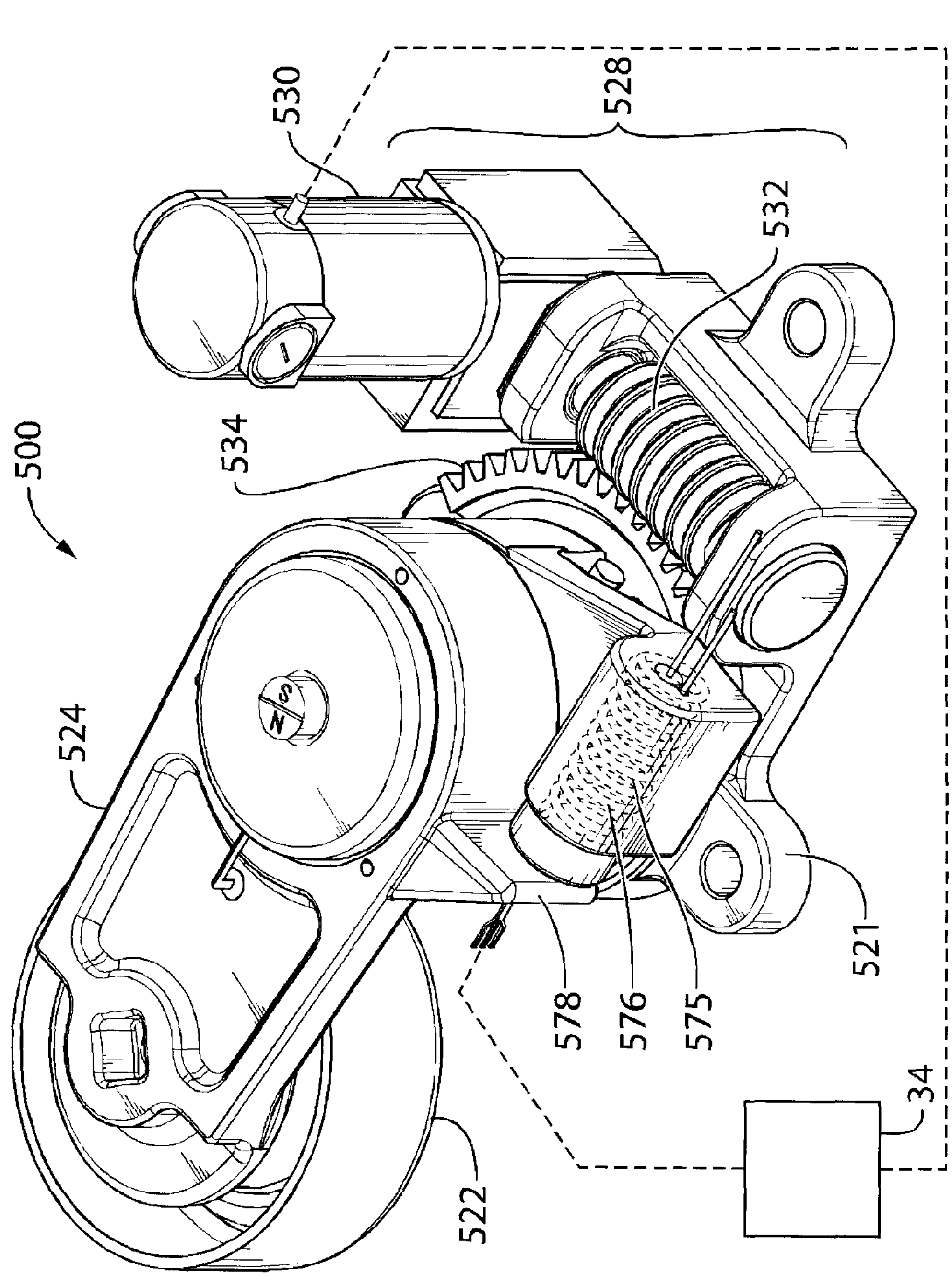


FIG.10

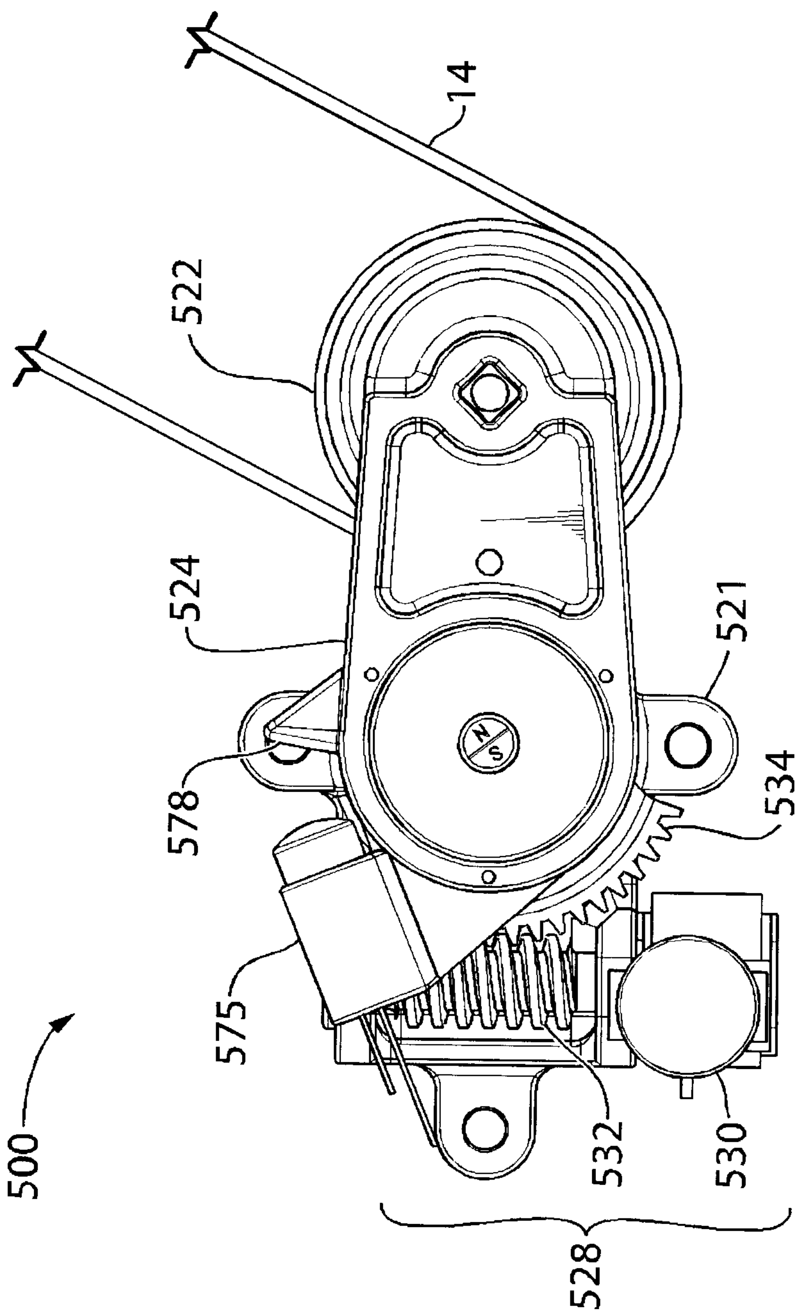


FIG. 11a

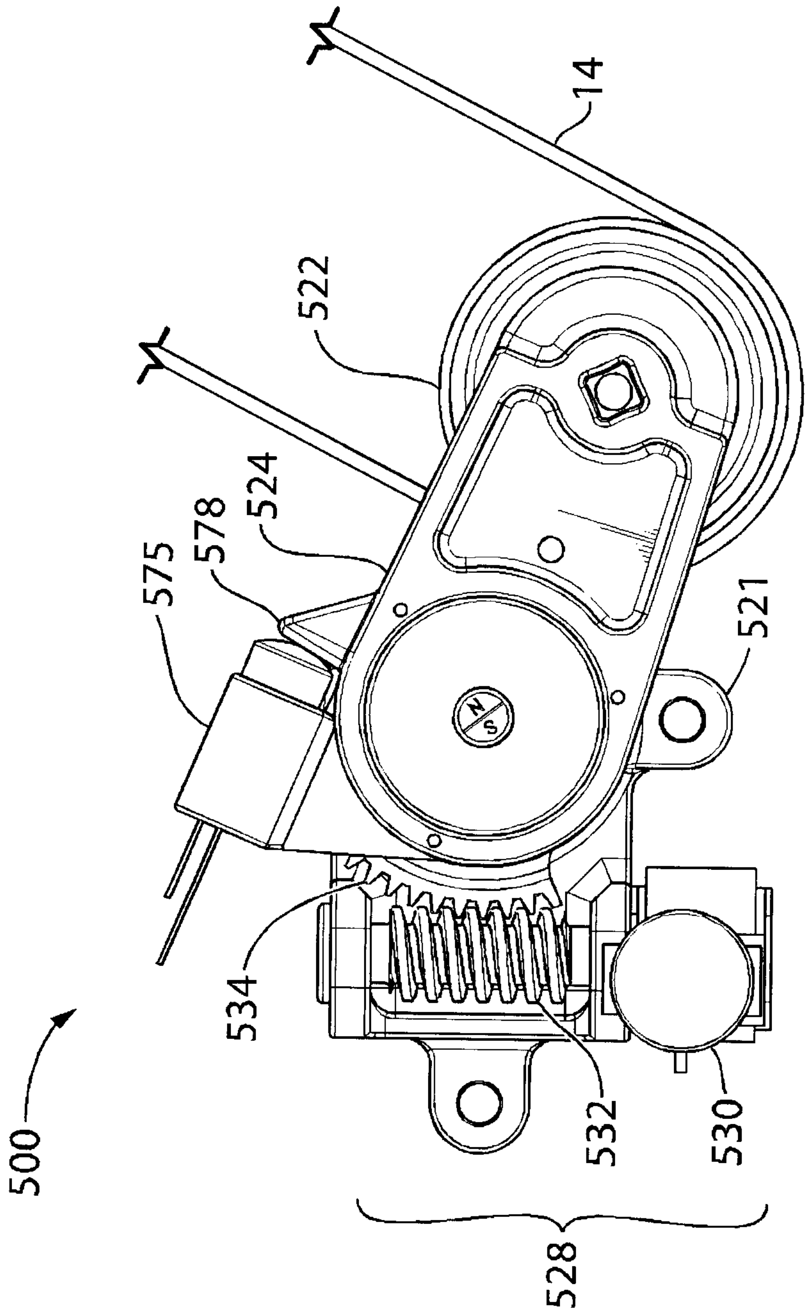
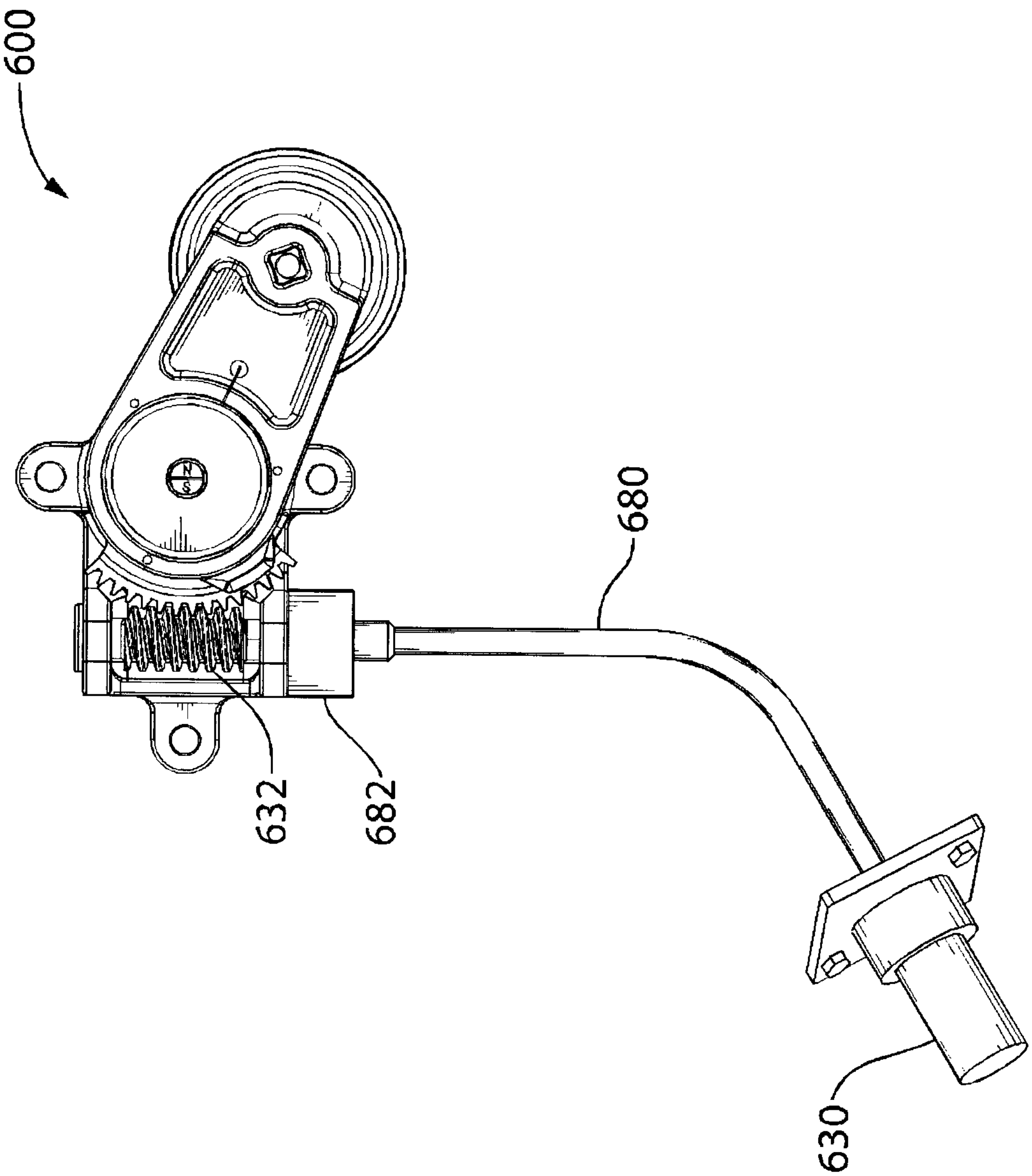


FIG.11b

FIG. 12



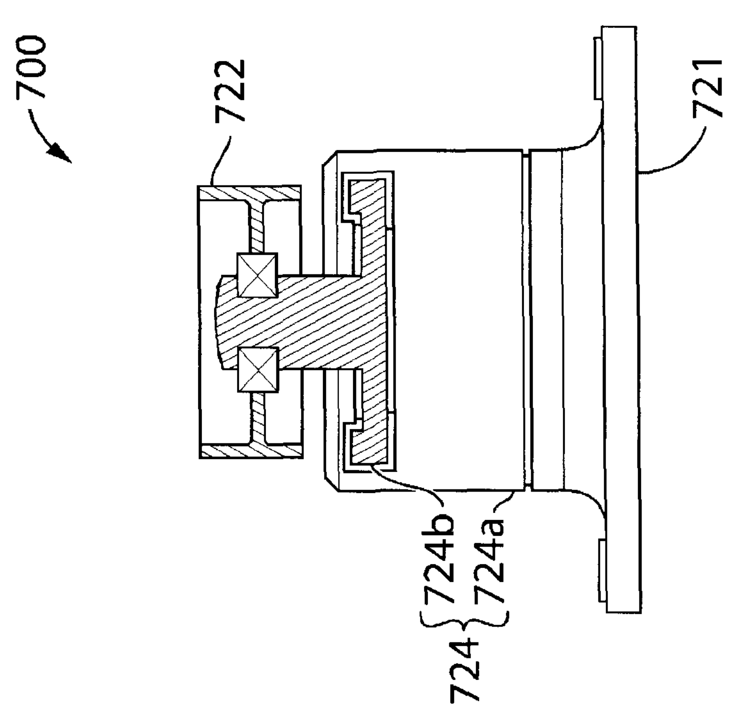


FIG.13b

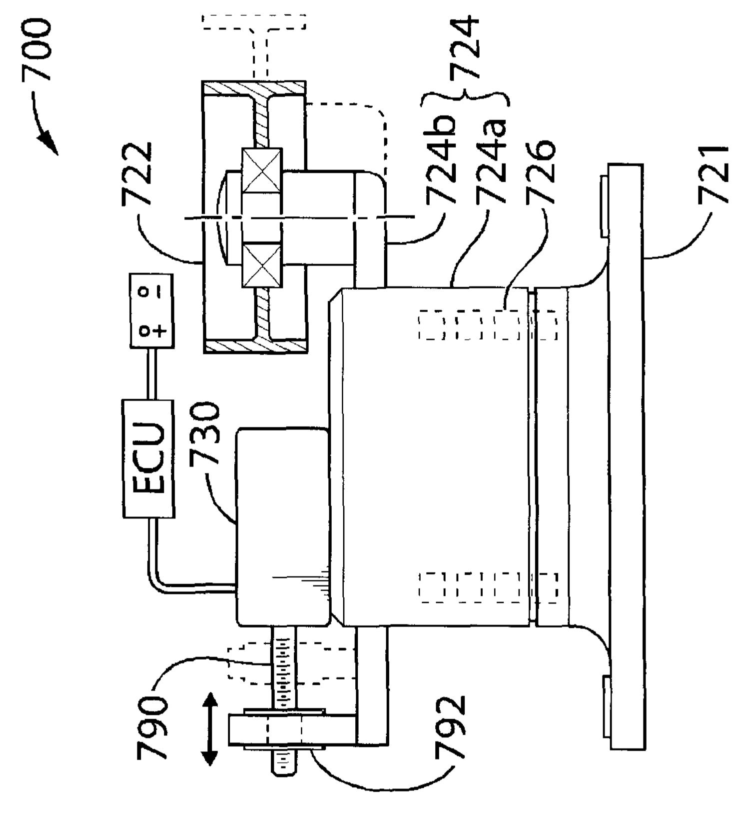


FIG.13a

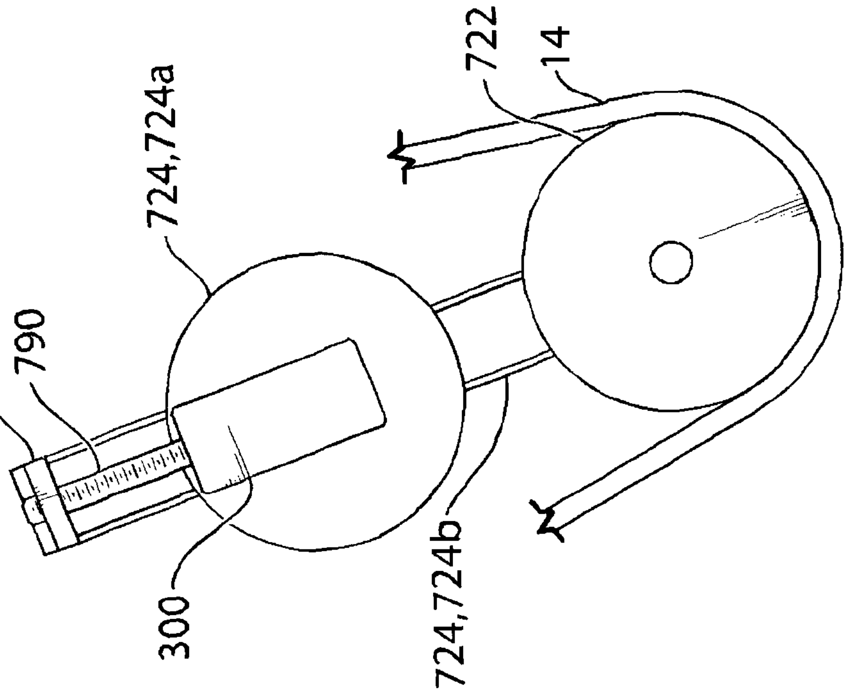


FIG.13d

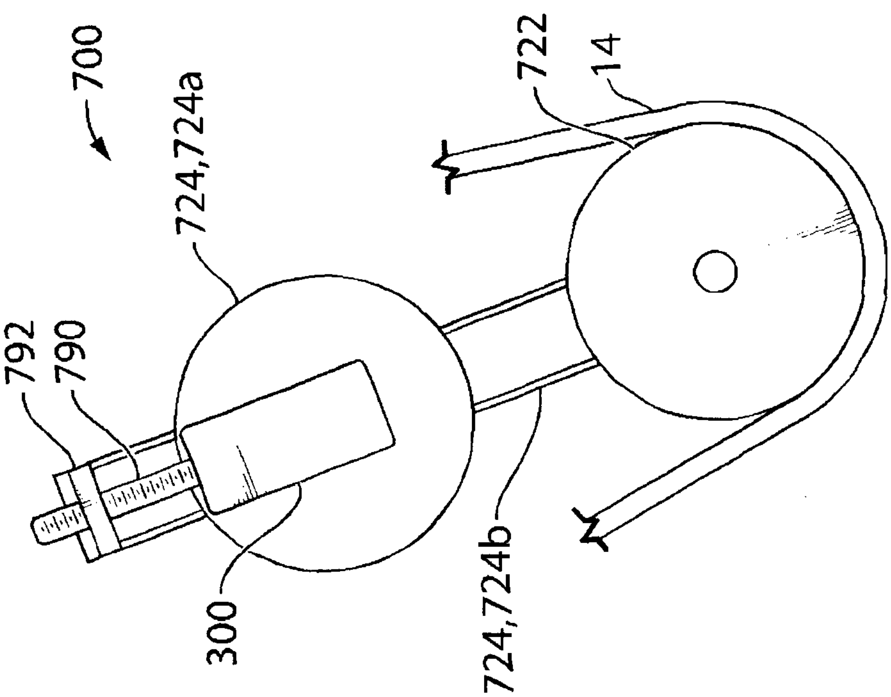


FIG.13c

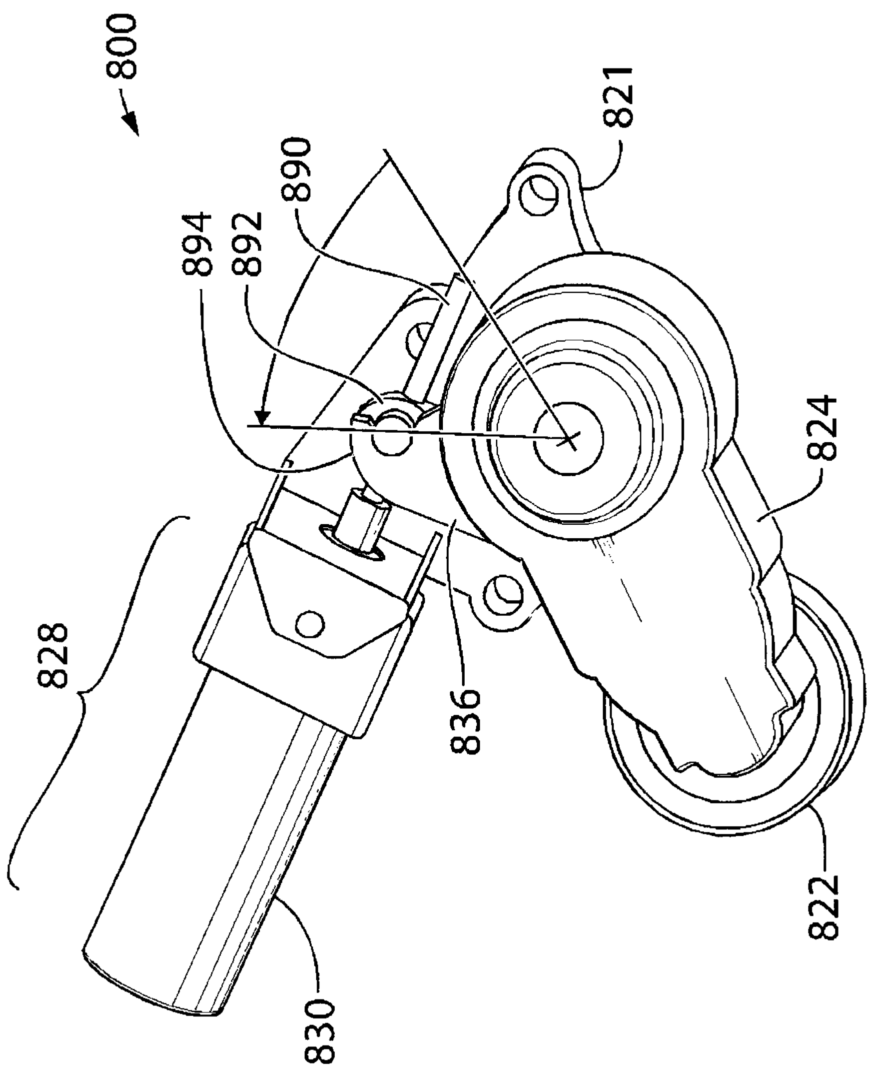
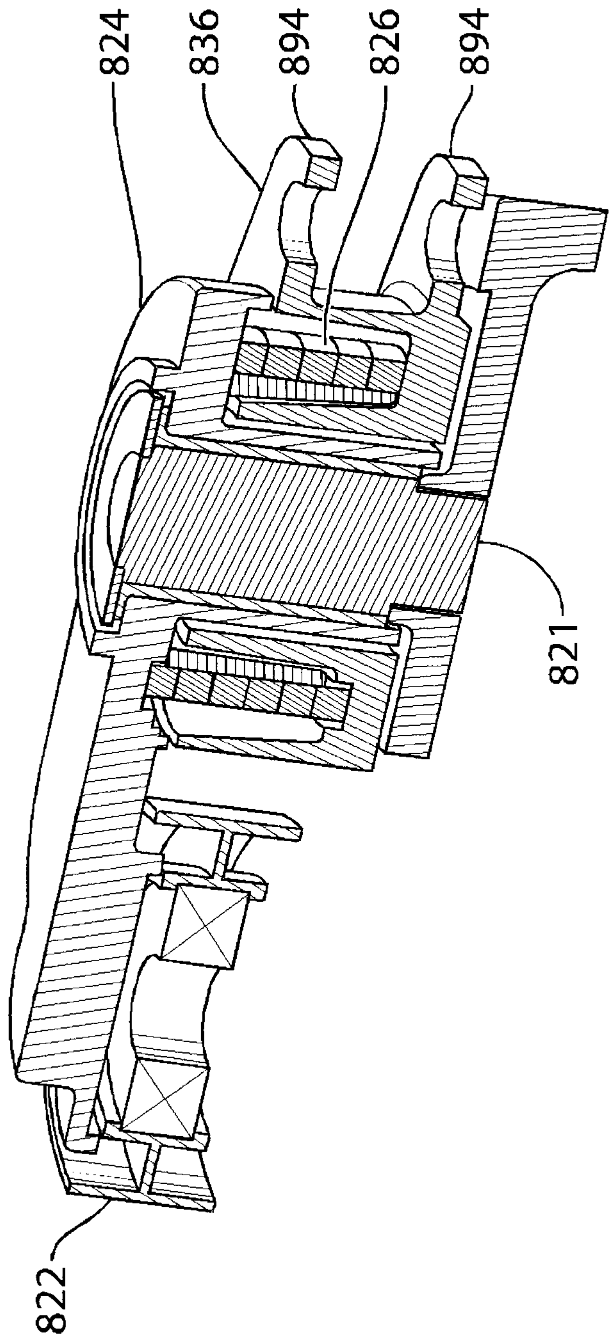


FIG.14a

FIG. 14b



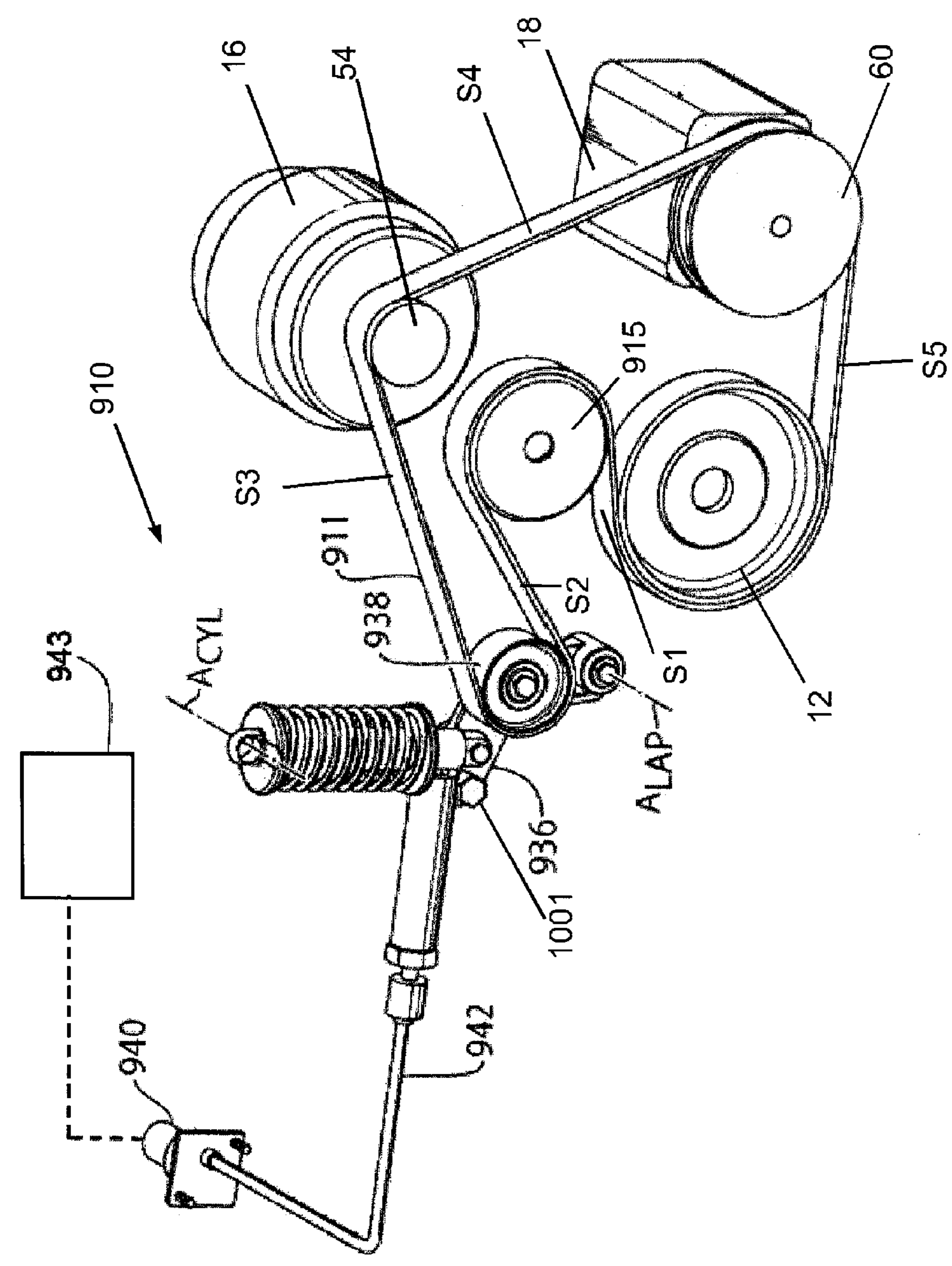

16
54
18
S4
60
910
915
S5
S3
911
S2
938
S1
12
943
ACYL
ALAP
936
1001
940
942

FIG.15

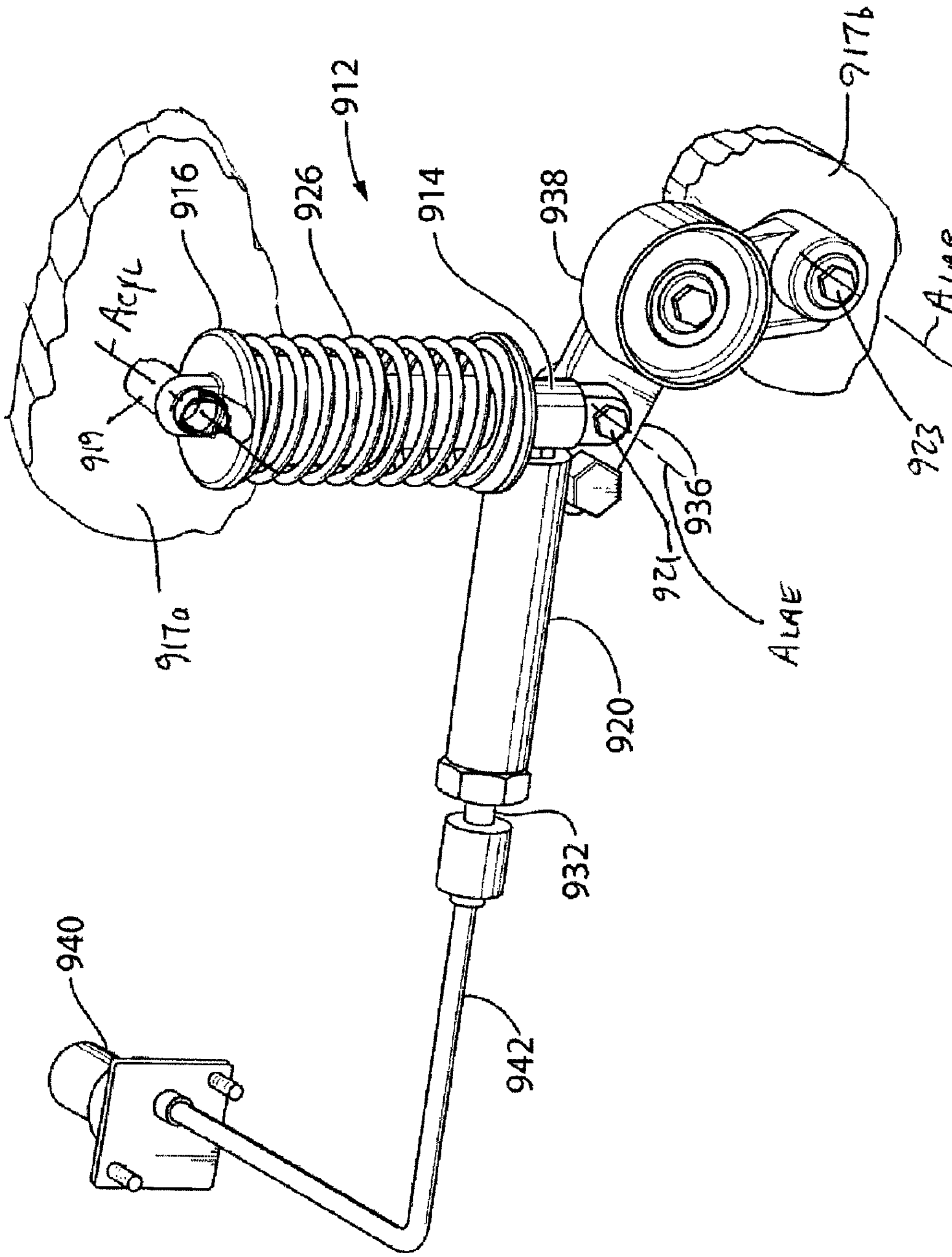

912
916
926
914
938
917b
917a
919
Acyl
920
932
940
942
936
921
923
Alae
Alap

FIG.16

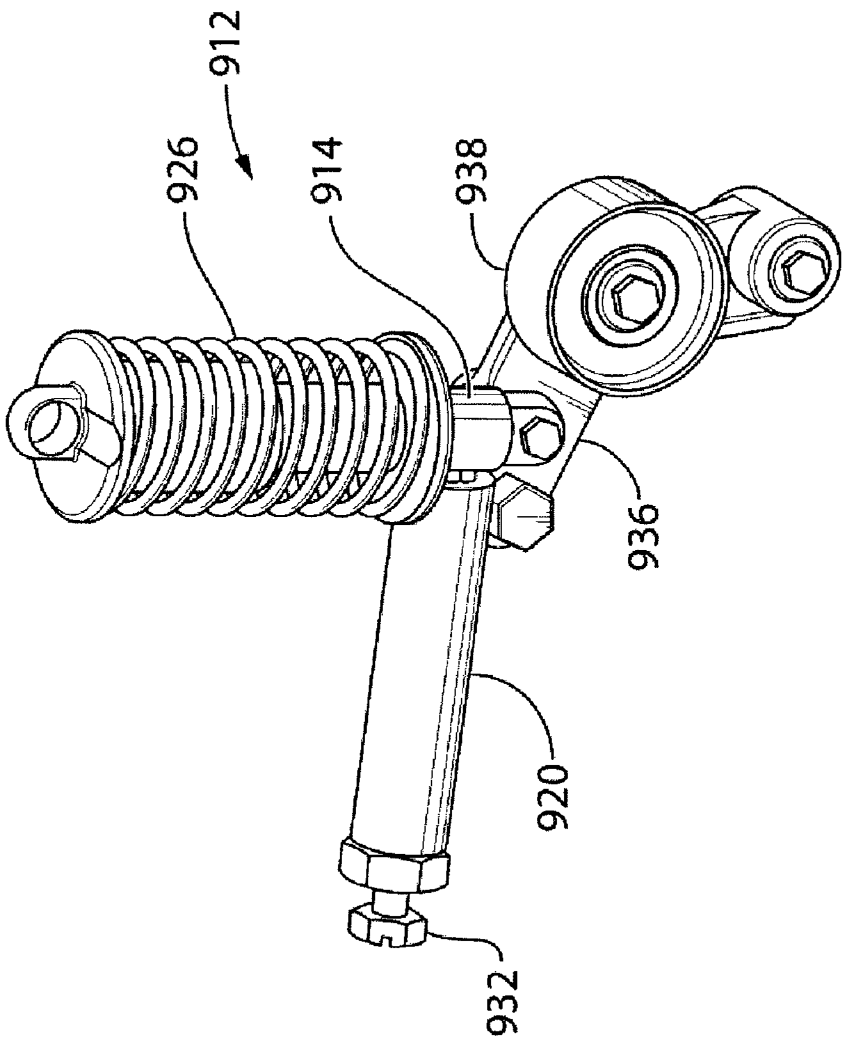


FIG.17

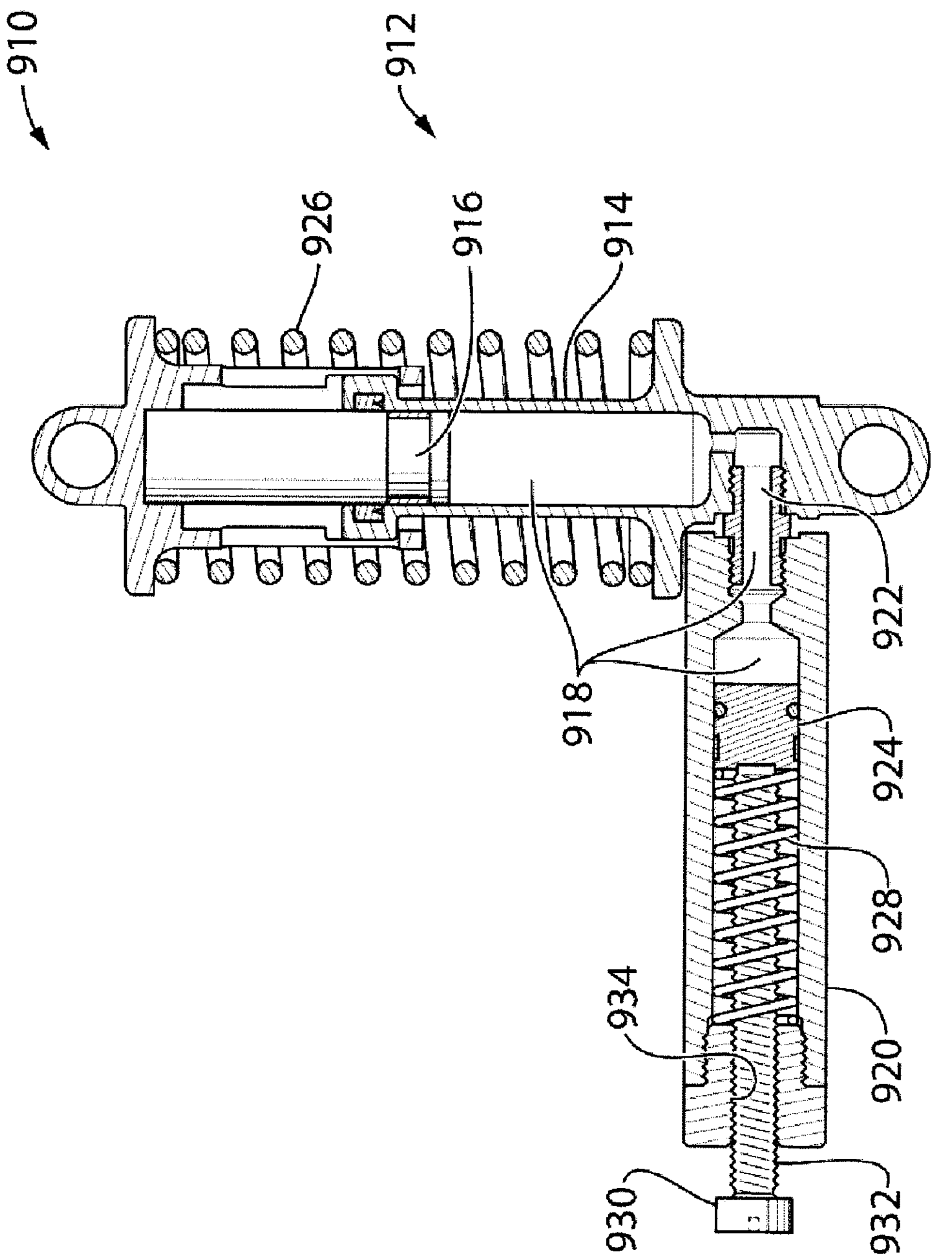


FIG. 18

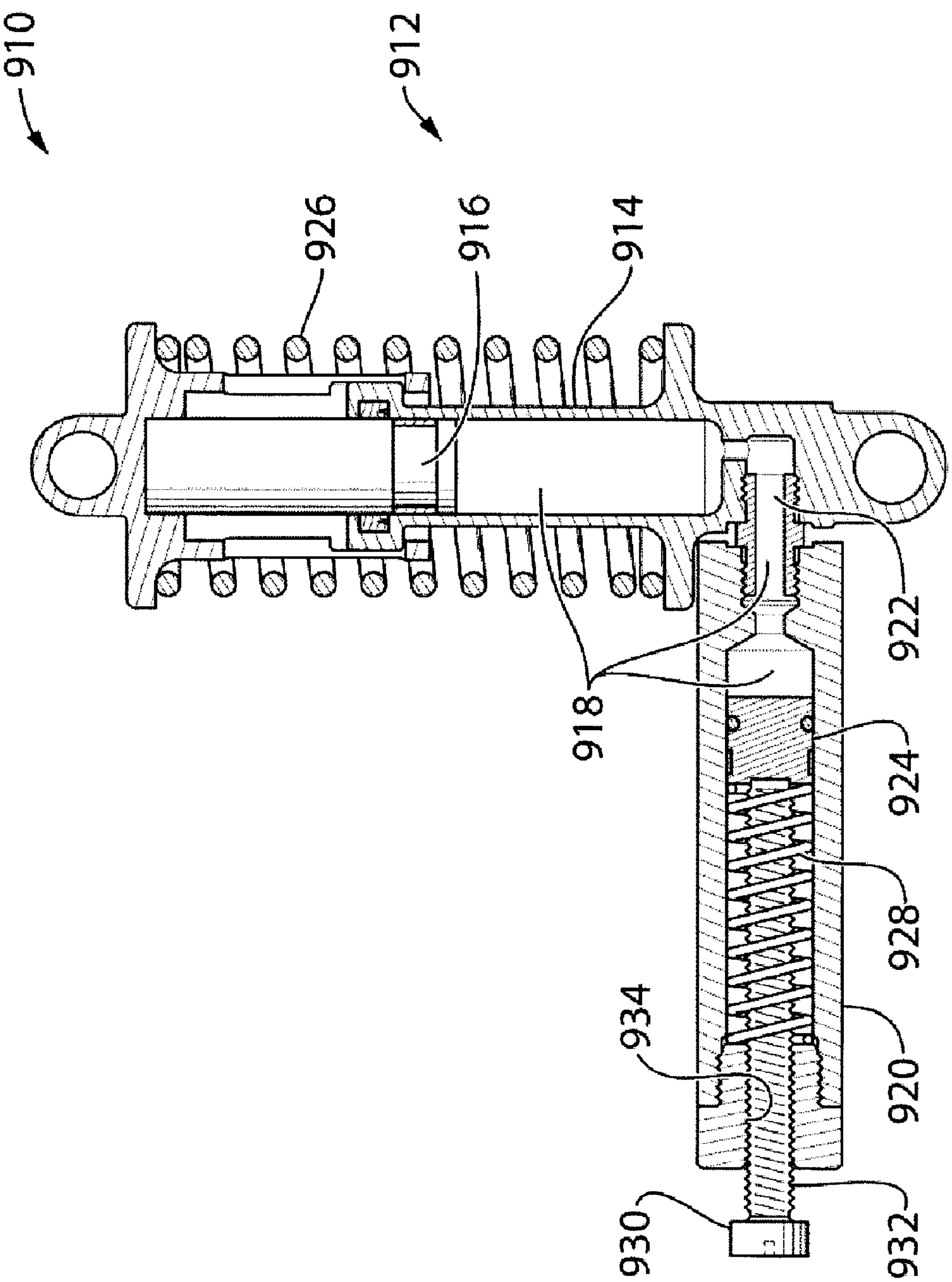


FIG.19

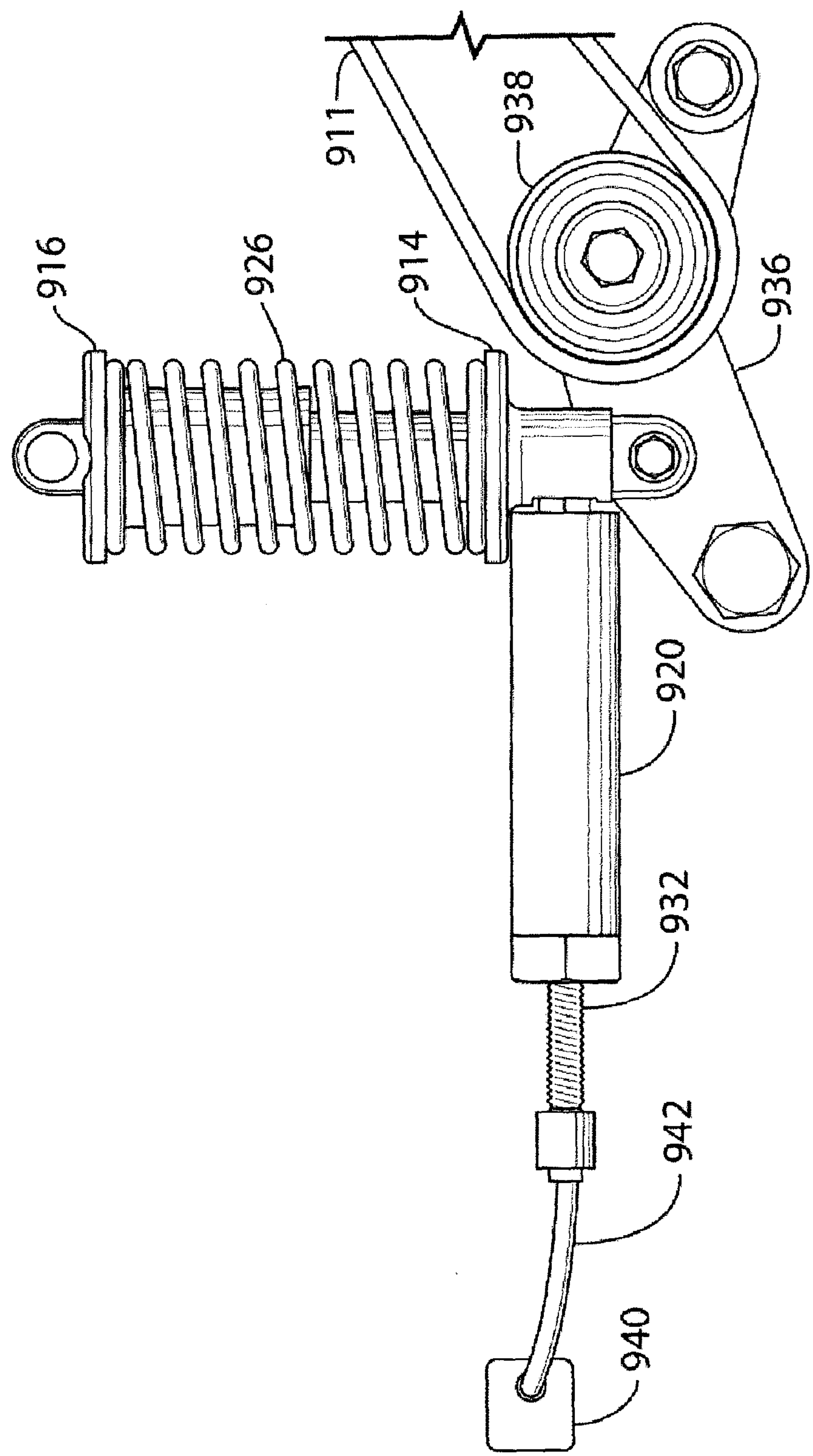


FIG. 20

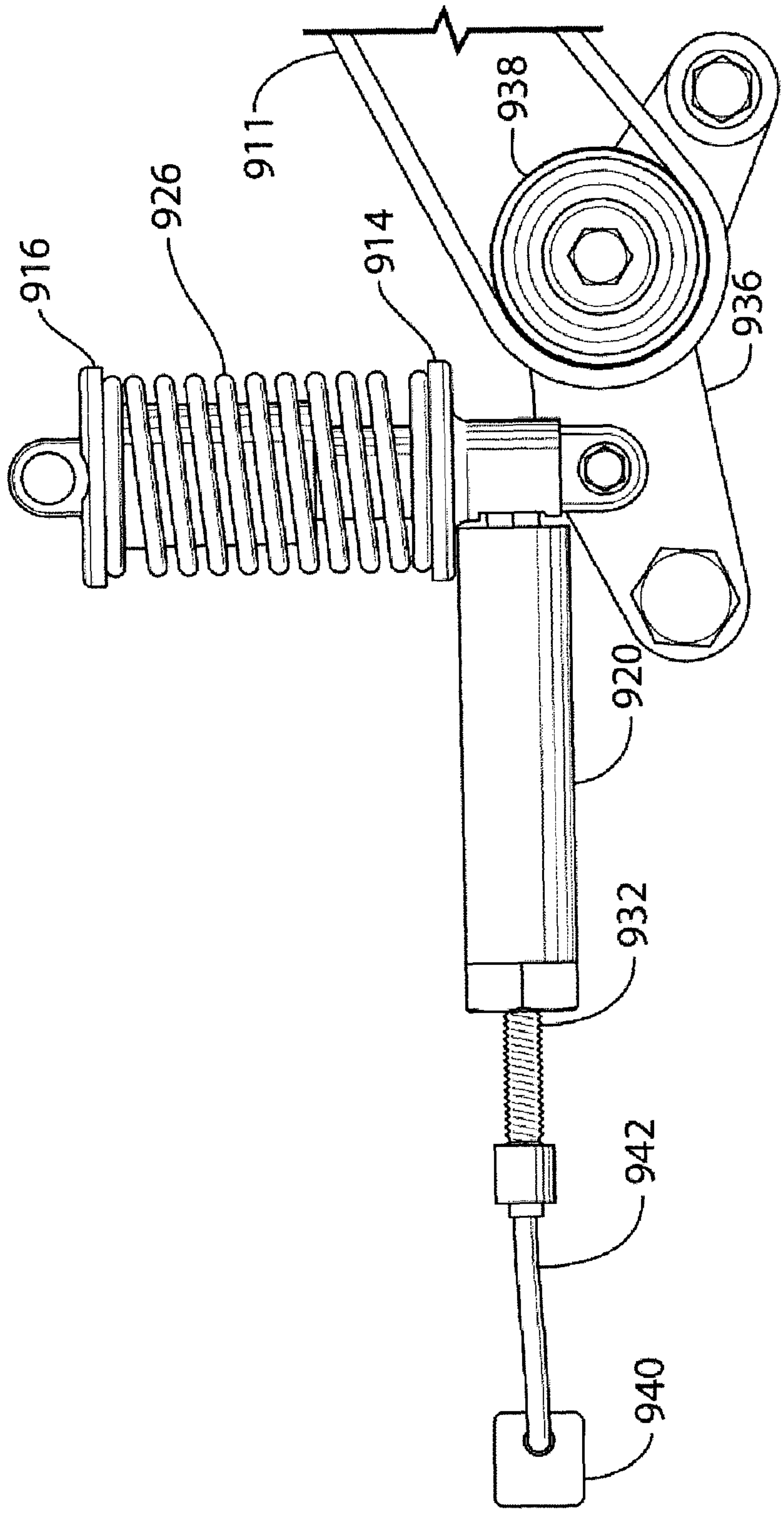


FIG. 21

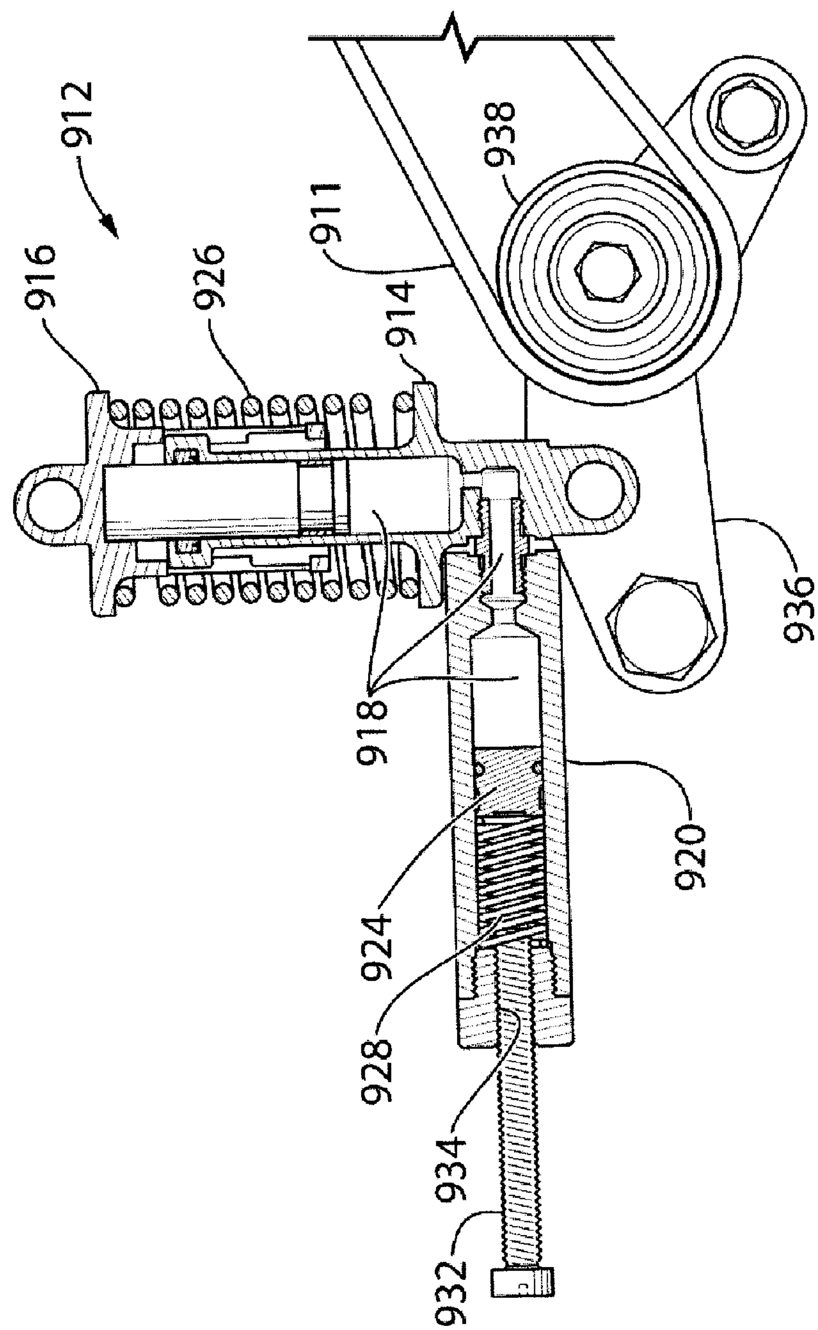


FIG. 22

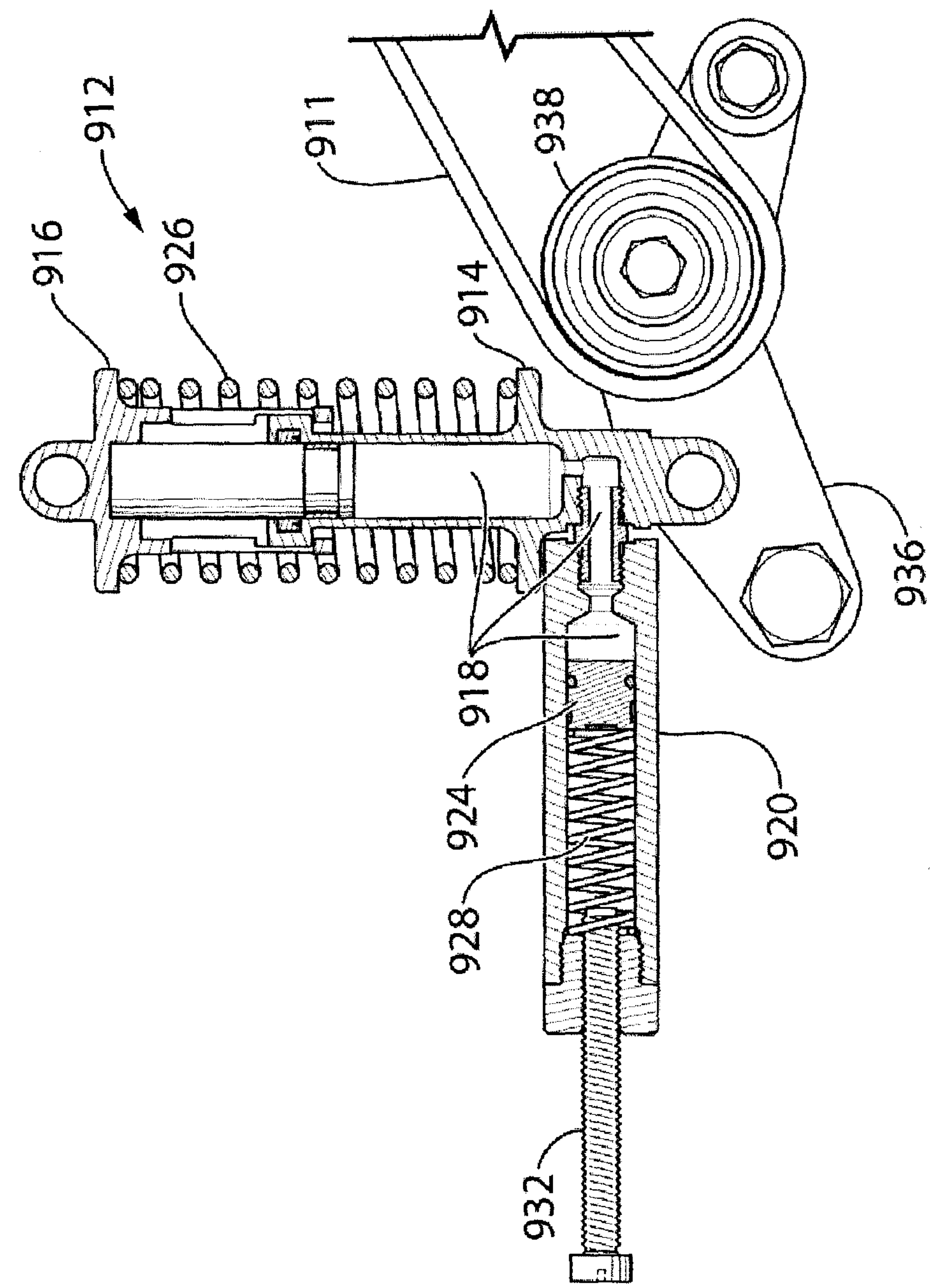


FIG. 23

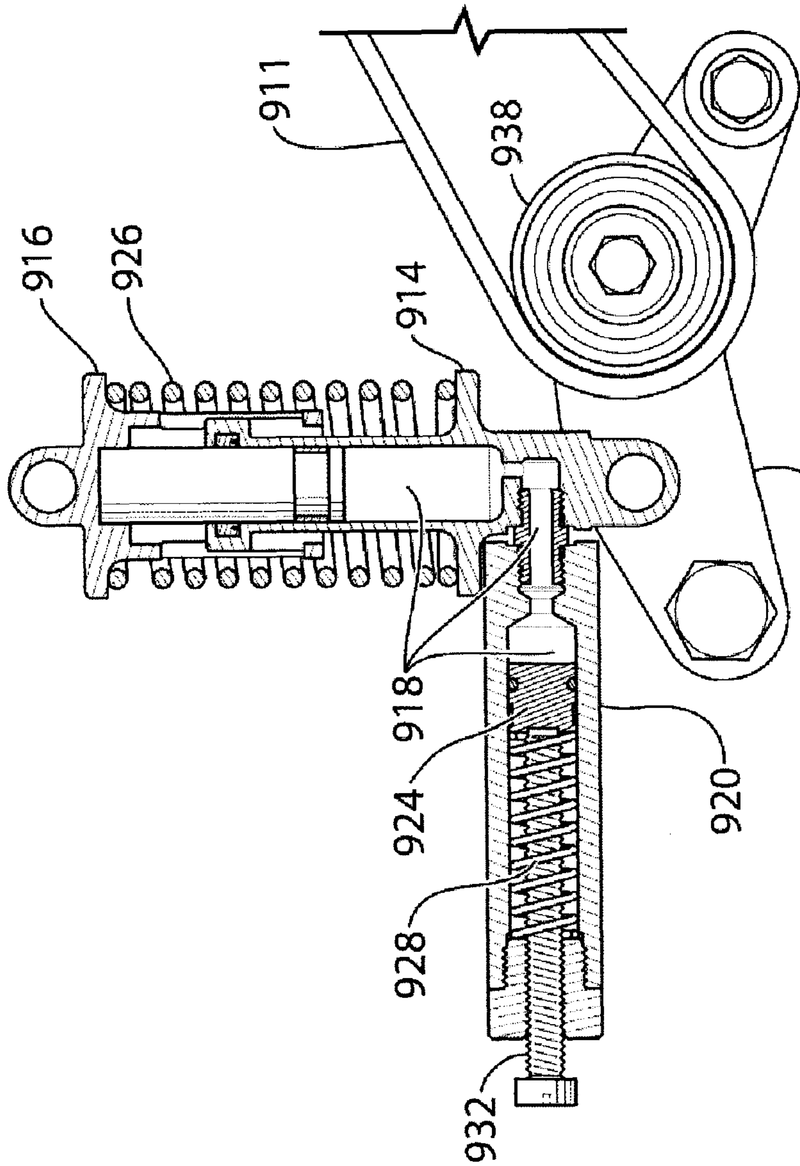


FIG. 24

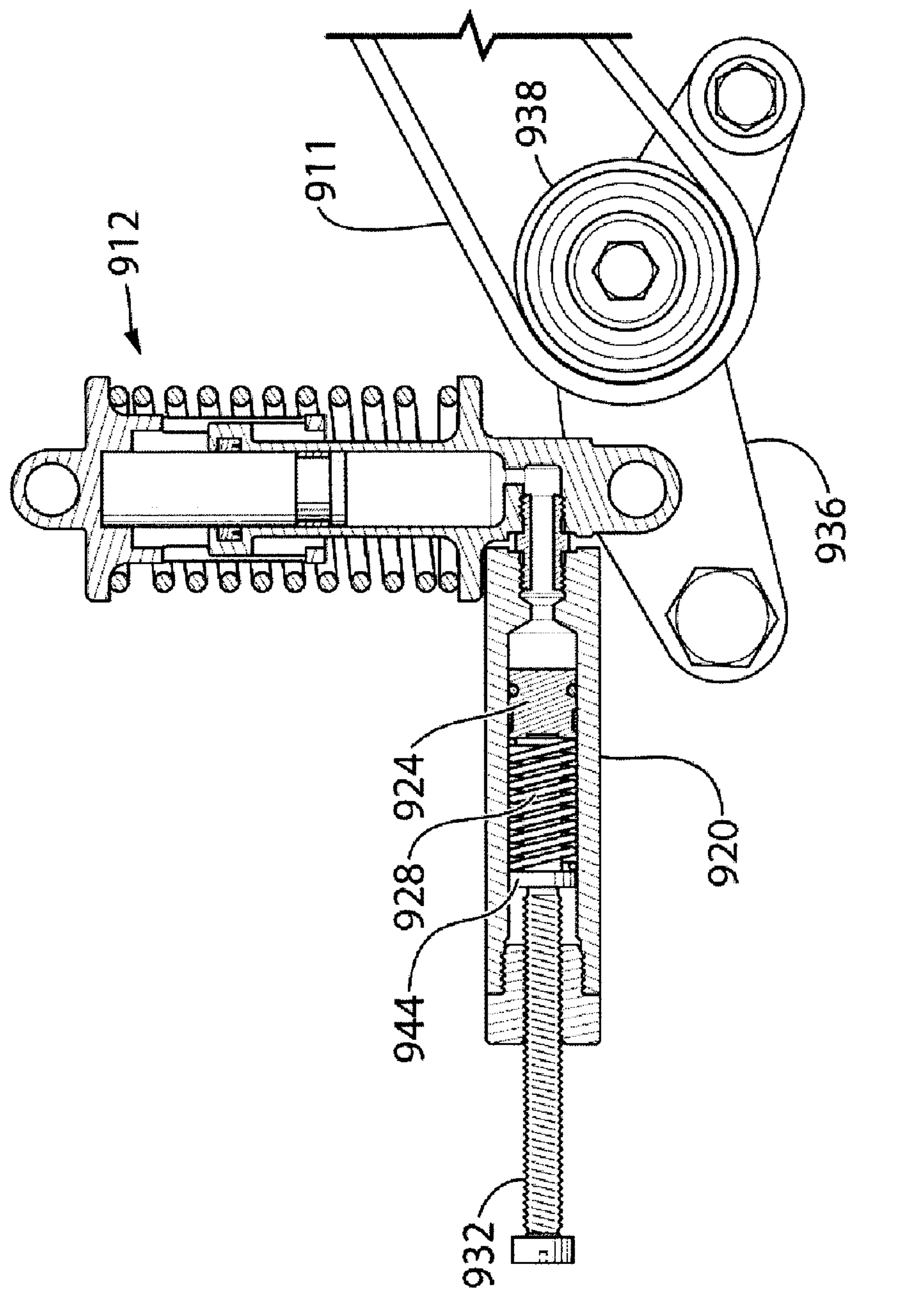
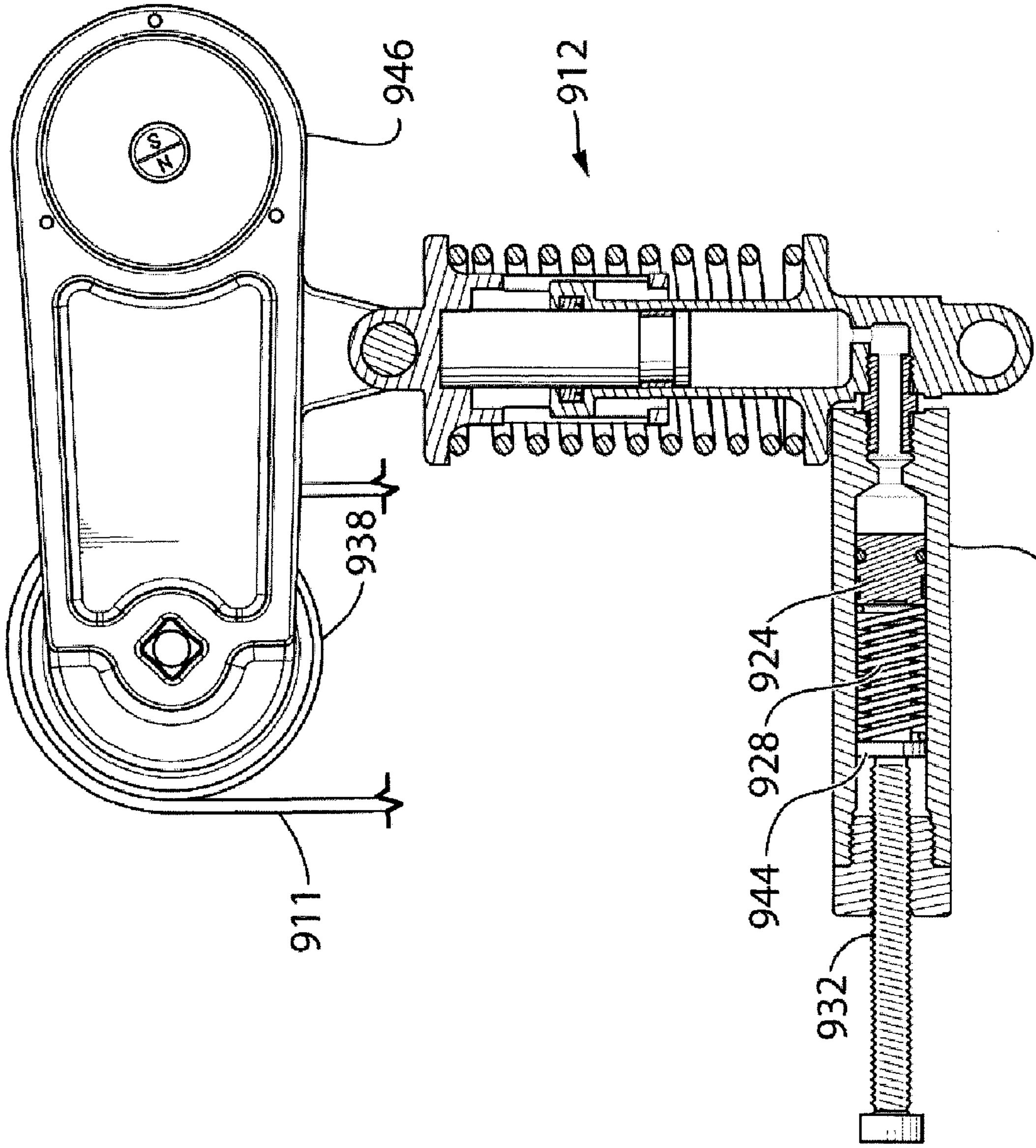


FIG. 25

FIG. 26



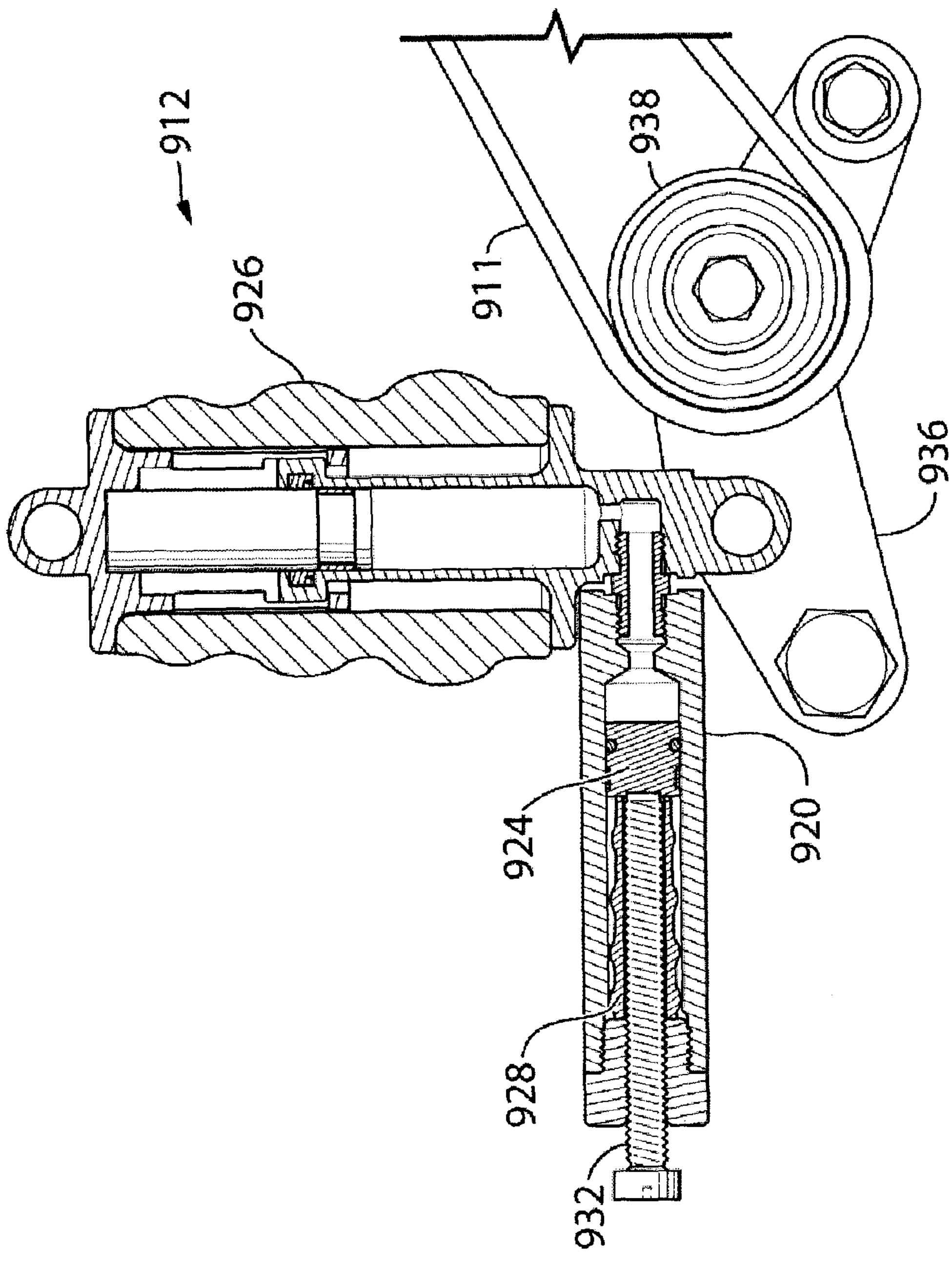


FIG. 27

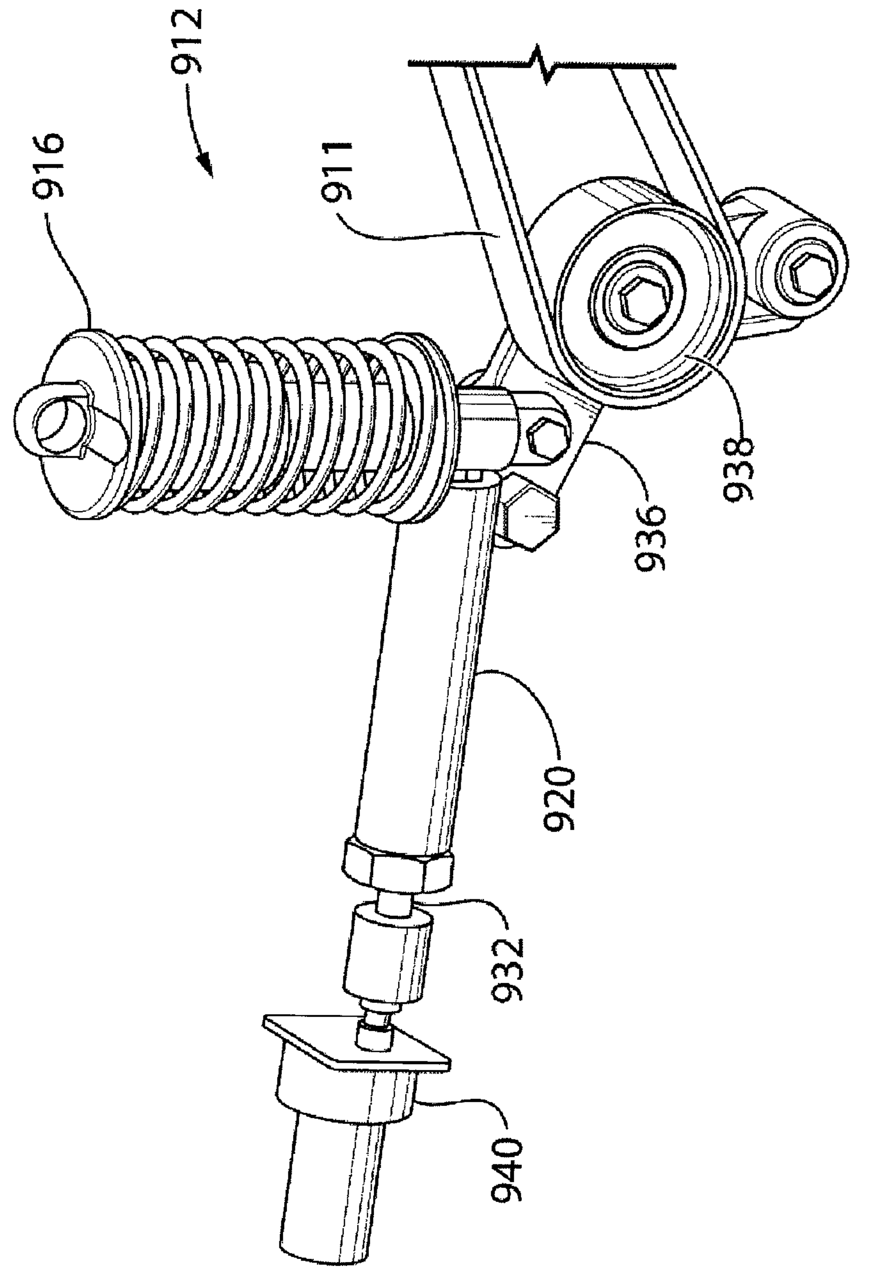


FIG. 28

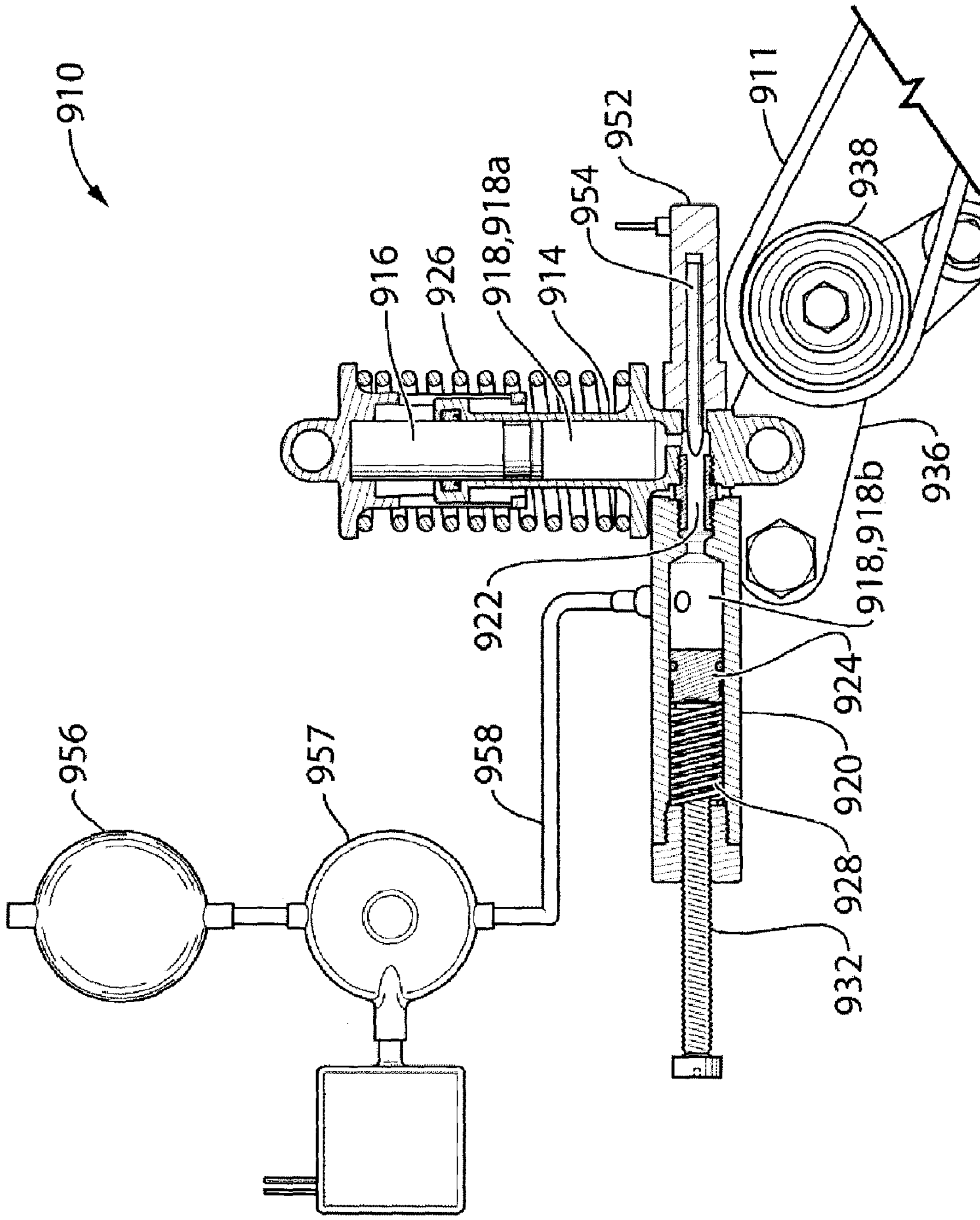
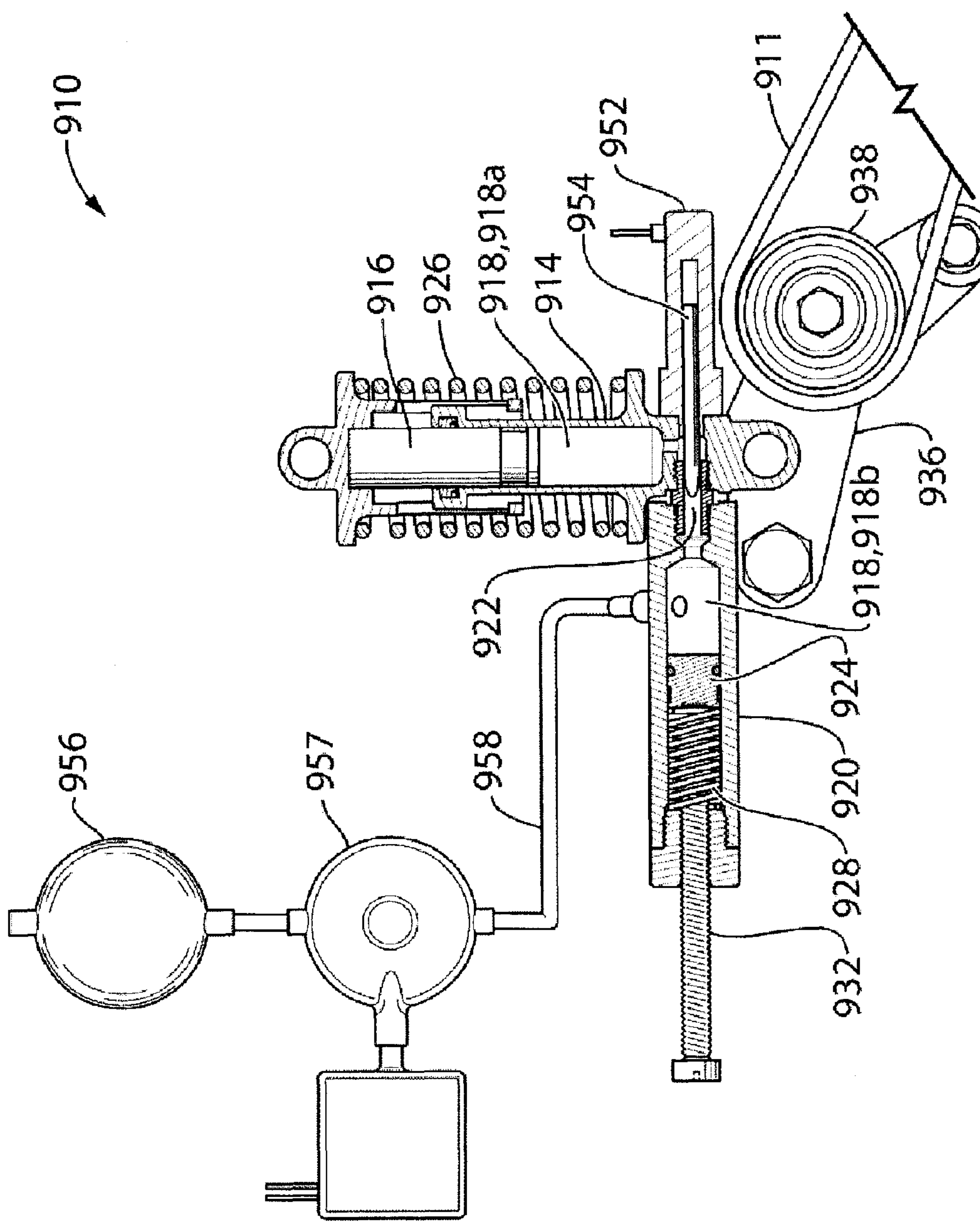

910
952
954
911
938
916
926
918,918a
914
936
918,918b
922
924
920
928
932
956
957
958

FIG. 29a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918,918a
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932
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957
956

FIG. 29b

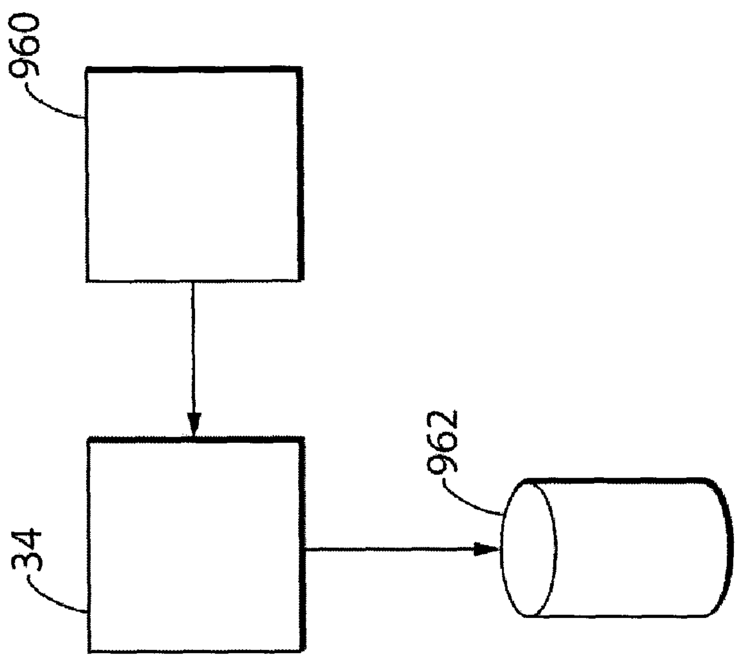
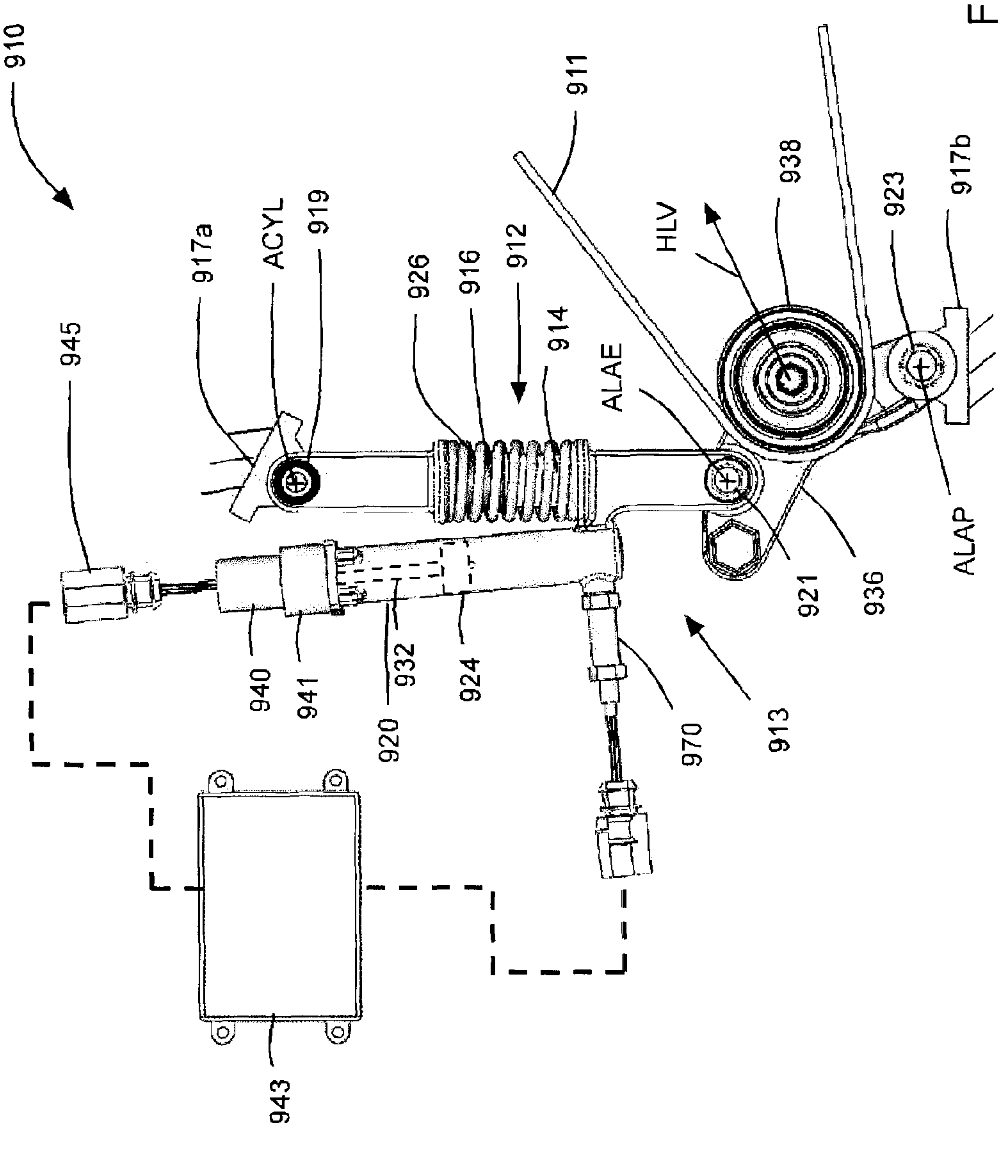


FIG. 30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911
912
913
914
916
917a
917b
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920
921
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926
932
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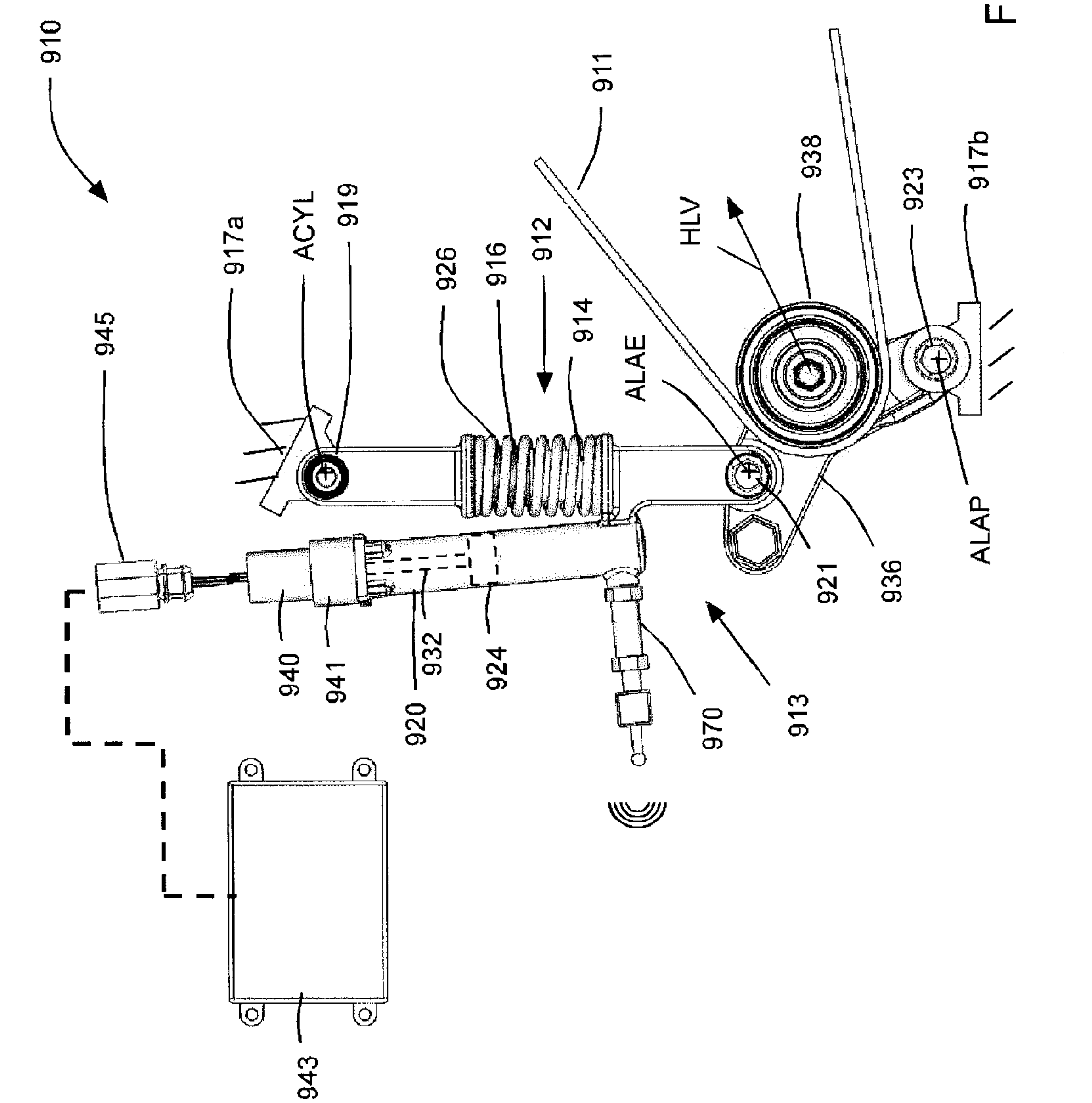
938
940
941
943
945
970
ACYL
ALAE
ALAP
HLV

FIG. 31A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917a
ACYL
919
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916
912
914
ALAE
HLV
938
923
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945
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936
ALAP
940
941
920
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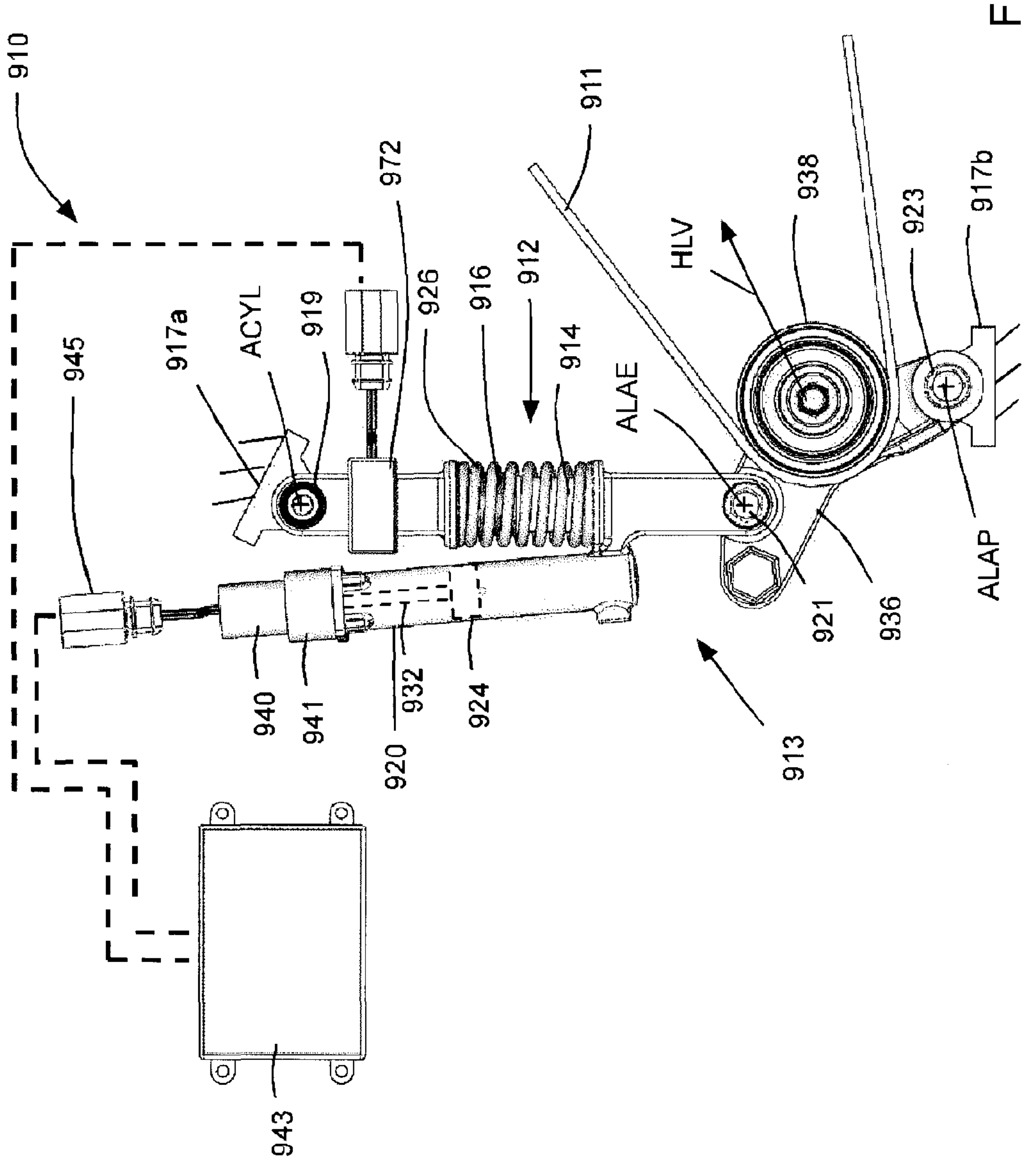
924
970
913
943

FIG. 31B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911
912
913
914
916
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920
921
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926
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938
940
941
943
945
972
ACYL
ALAE
ALAP
HLV

FIG. 32

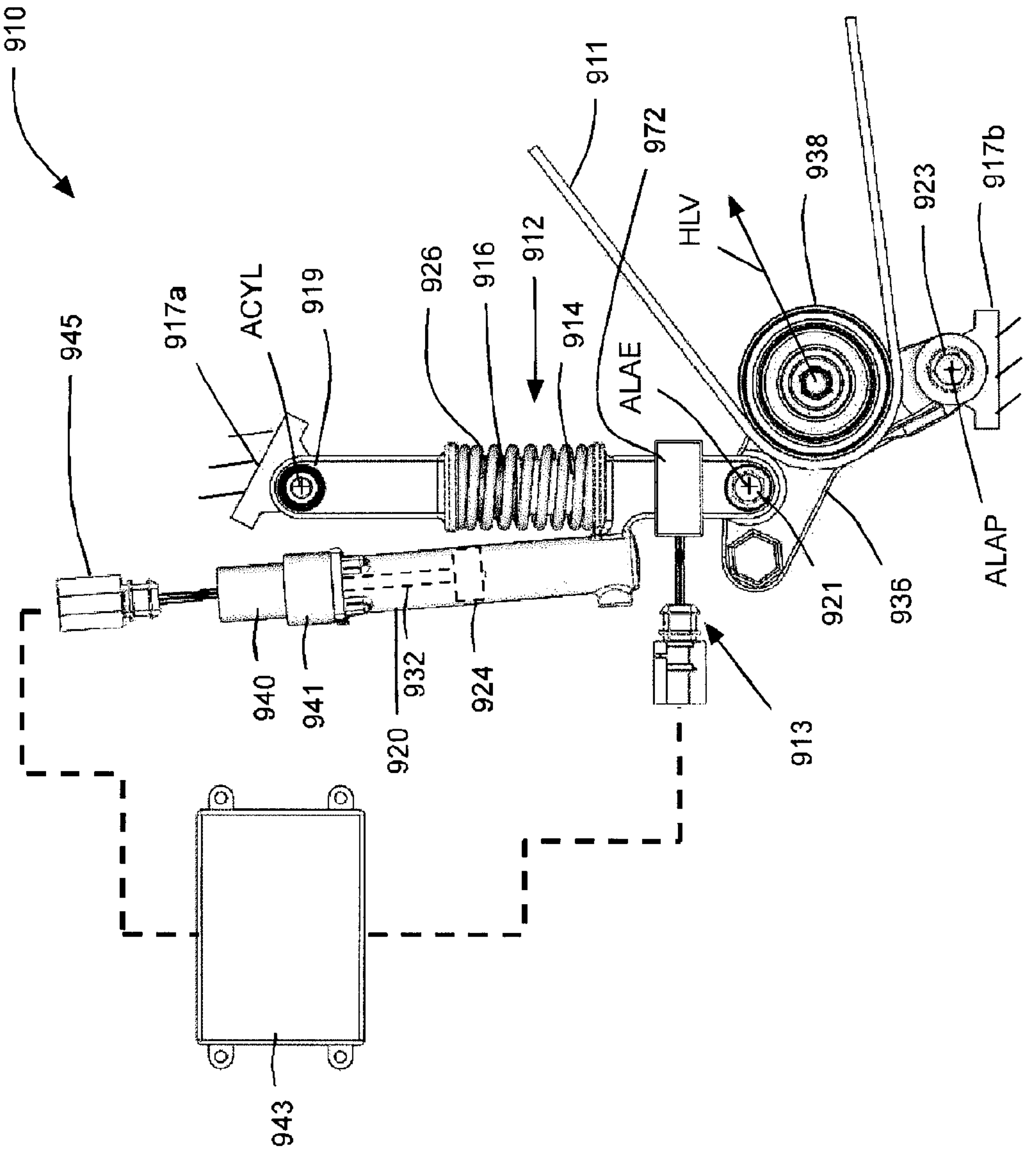
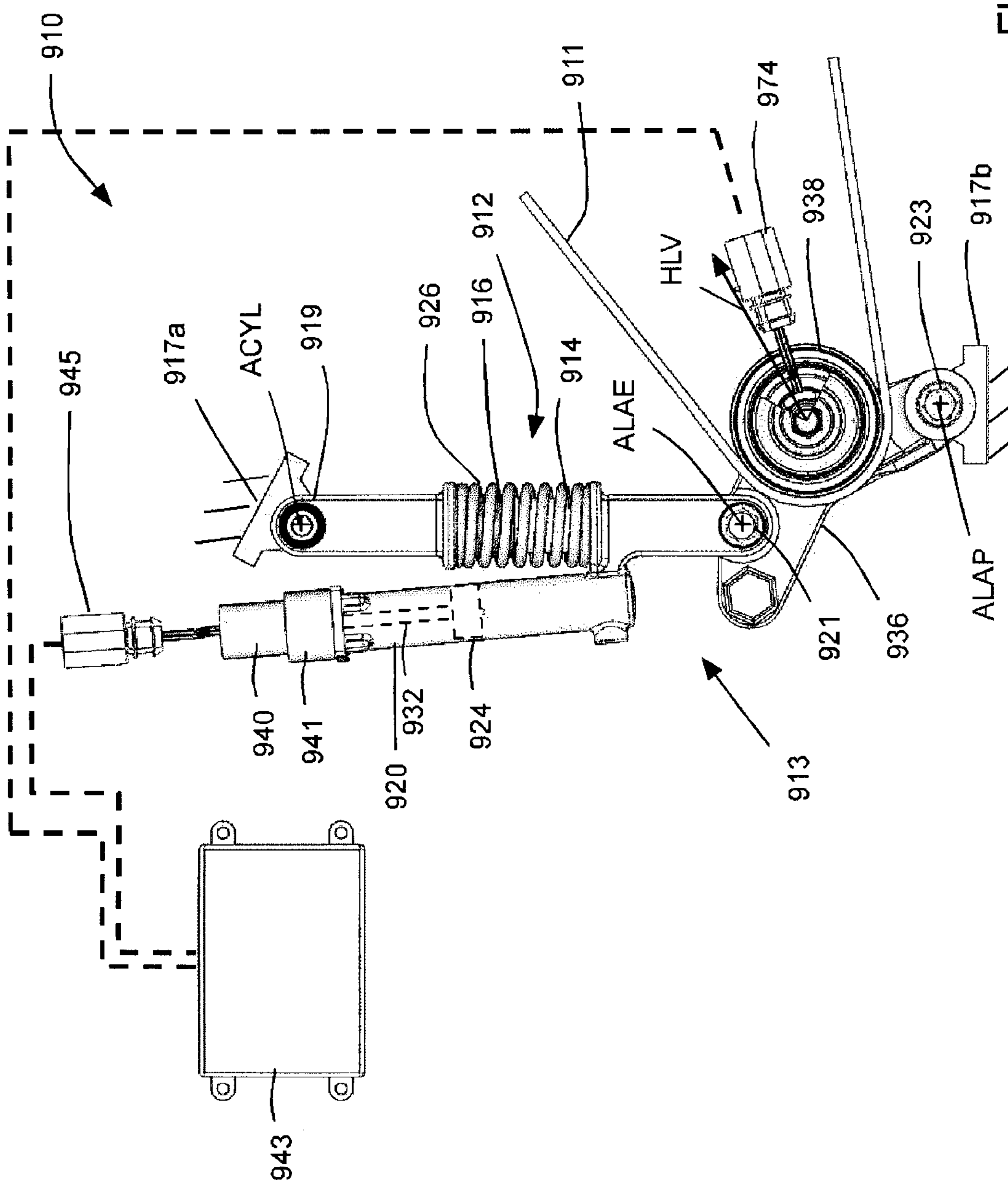

910
911
972
938
923
917b
HLV
912
916
926
919
ACYL
917a
945
914
ALAE
921
936
ALAP
940
941
920
932
924
913
943

FIG. 33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ACYL
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917b
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ALAP
940
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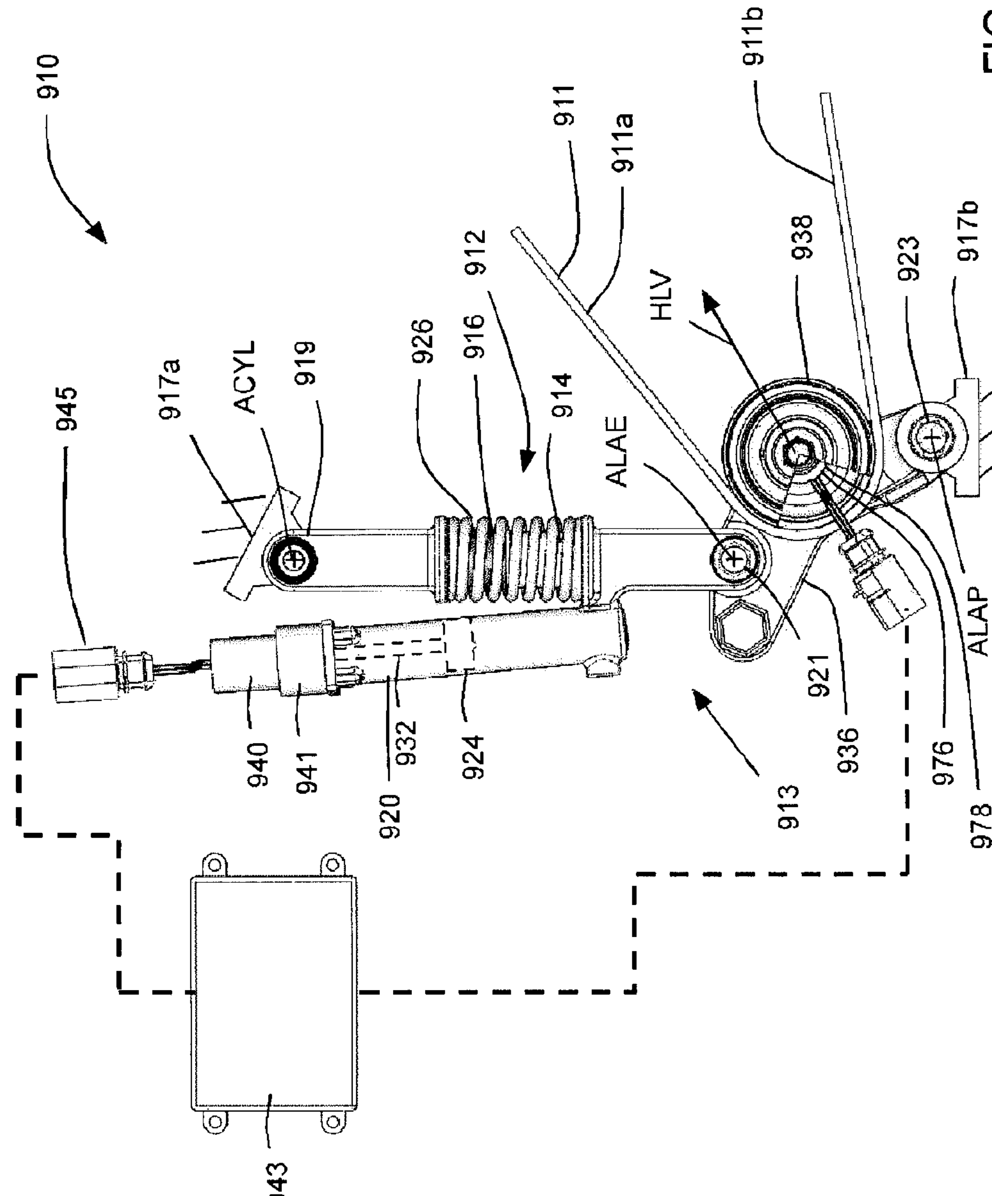
932
920
924
913
943

FIG. 34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945
917a
ACYL
919
926
916
912
914
ALAE
911
911a
938
HLV
911b
923
917b
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936
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978
ALAP
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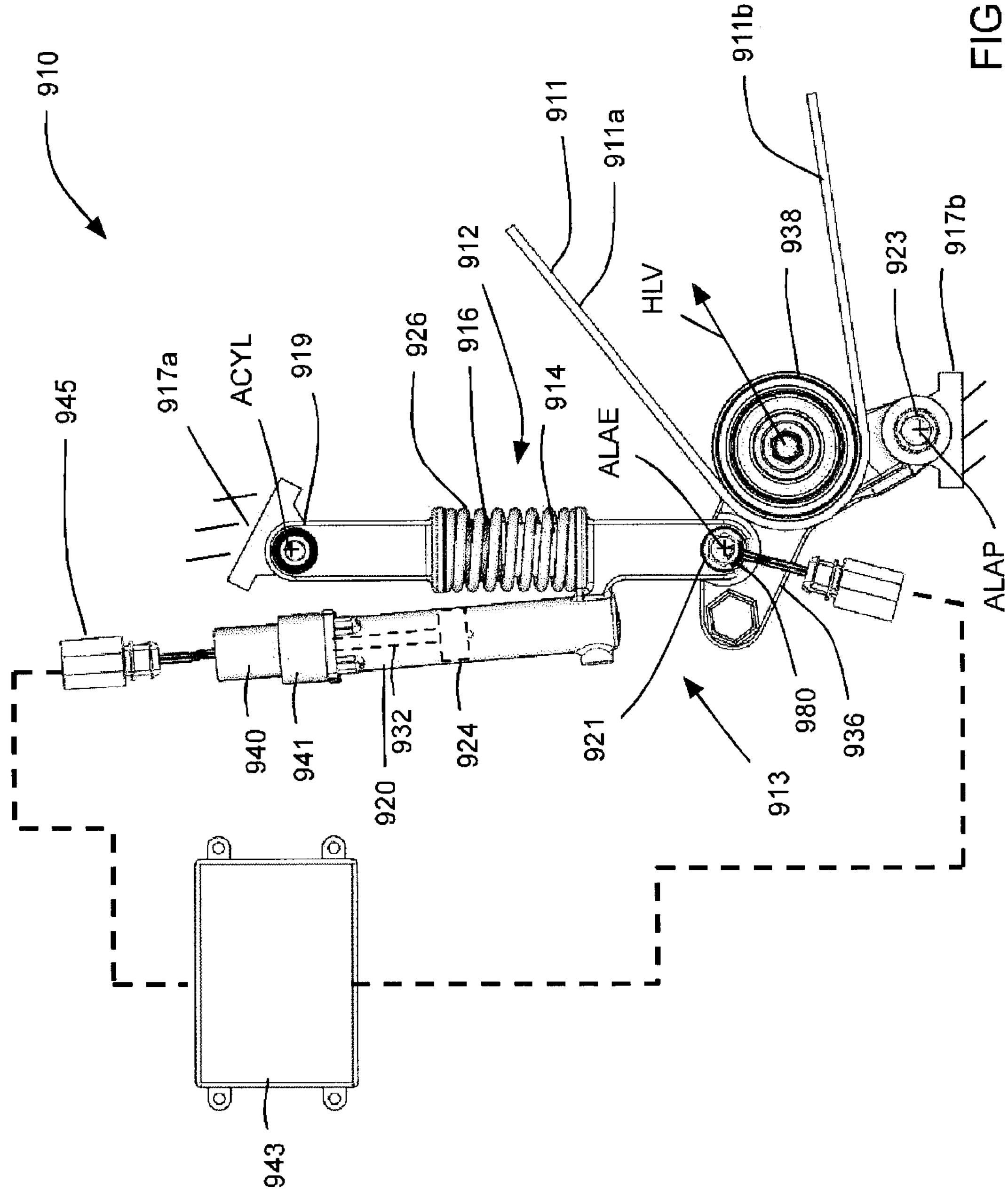
924
932
920
941
940
943

FIG. 35



910
911
911a
911b
912
913
914
916
917a
917b
919
920
921
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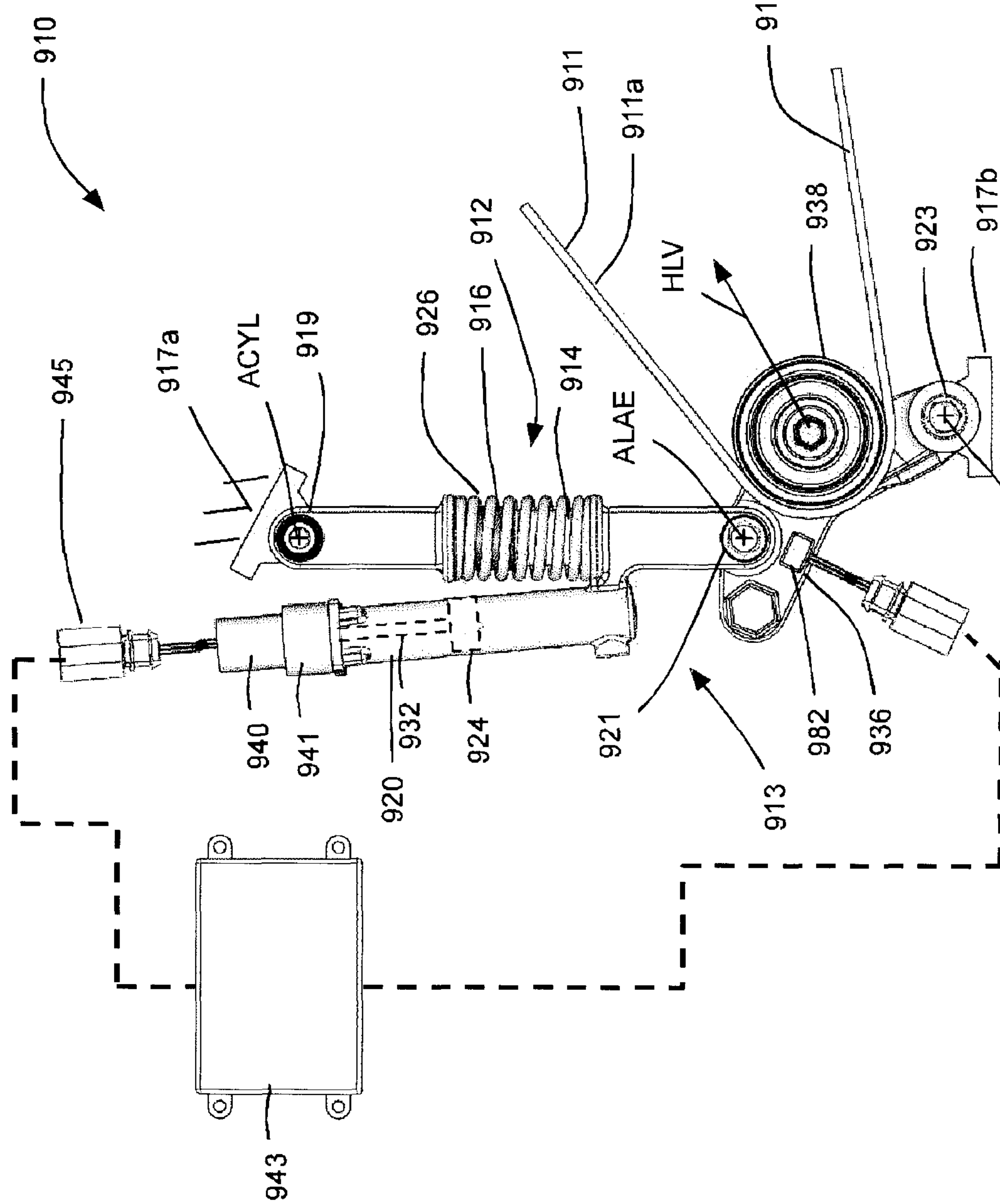
926
932
936
938
940
941
943
945
980
HLV
ALAE
ALAP
ACYL

FIG. 36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911
911a
911b
912
913
914
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917a
917b
919
920
921
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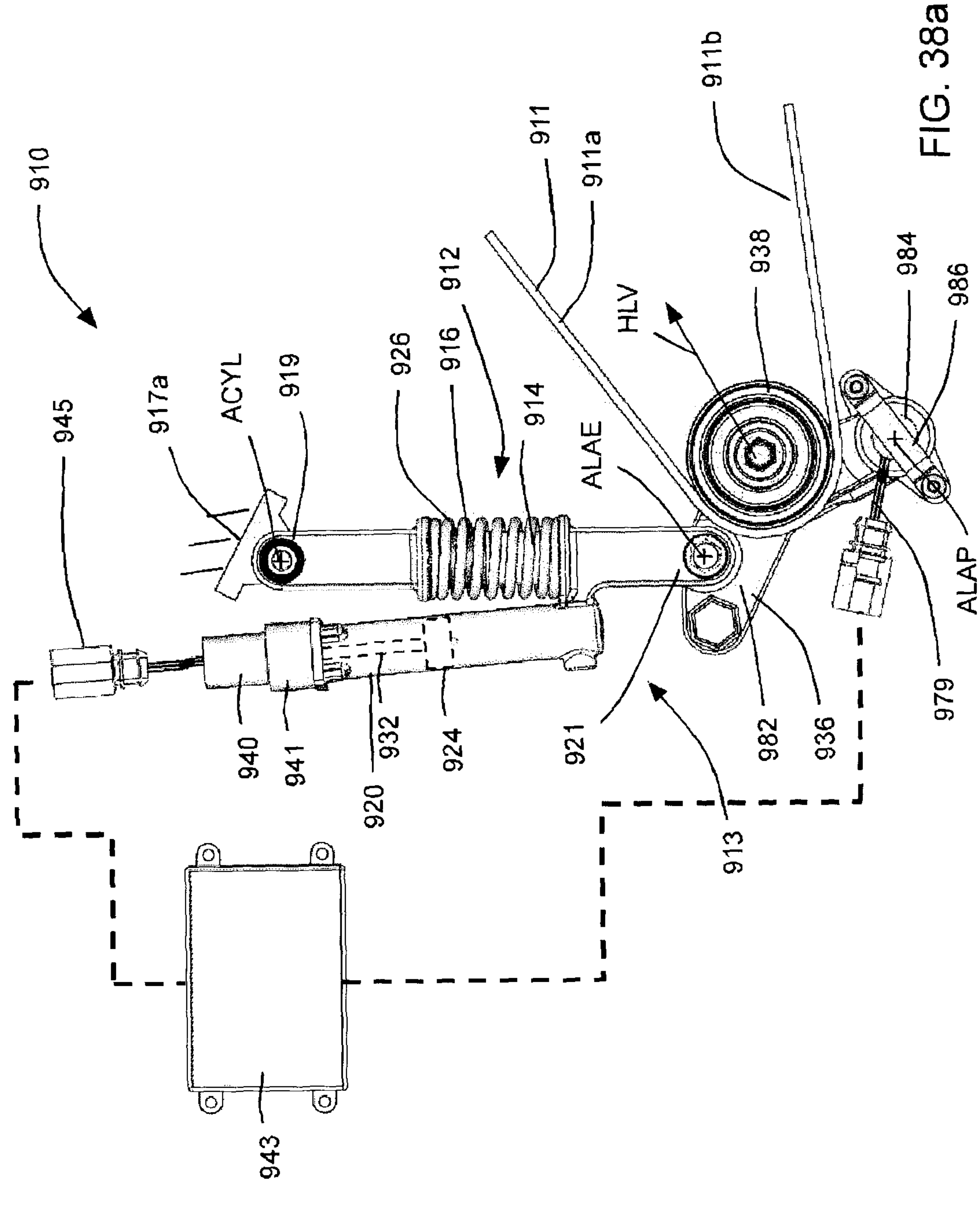
926
932
936
938
940
941
943
945
982
ACYL
ALAE
ALAP
HLV

FIG. 37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ACYL
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926
916
912
914
911
911a
911b
ALAE
HLV
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984
986
ALAP
979
936
982
913
921
924
932
920
941
940
943

FIG. 38a

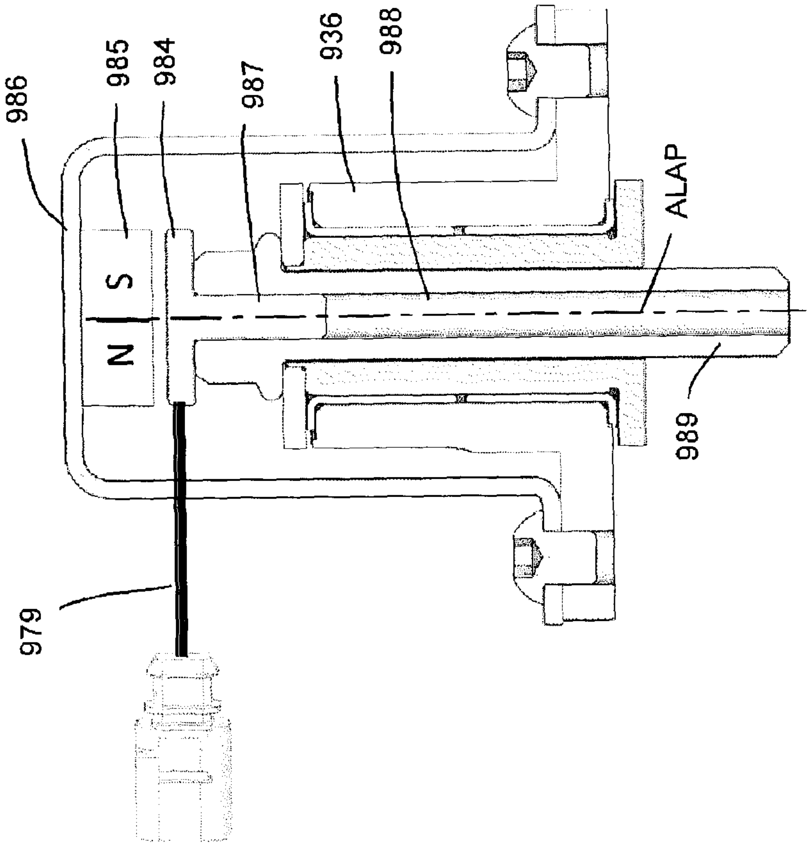

FIG. 38c

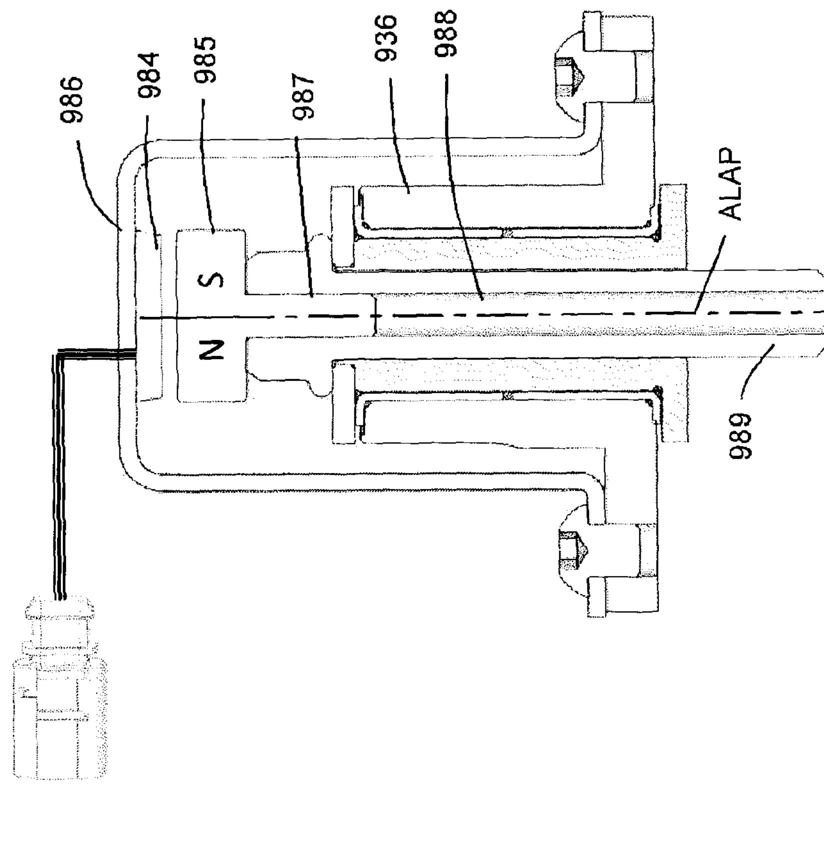

FIG. 38b

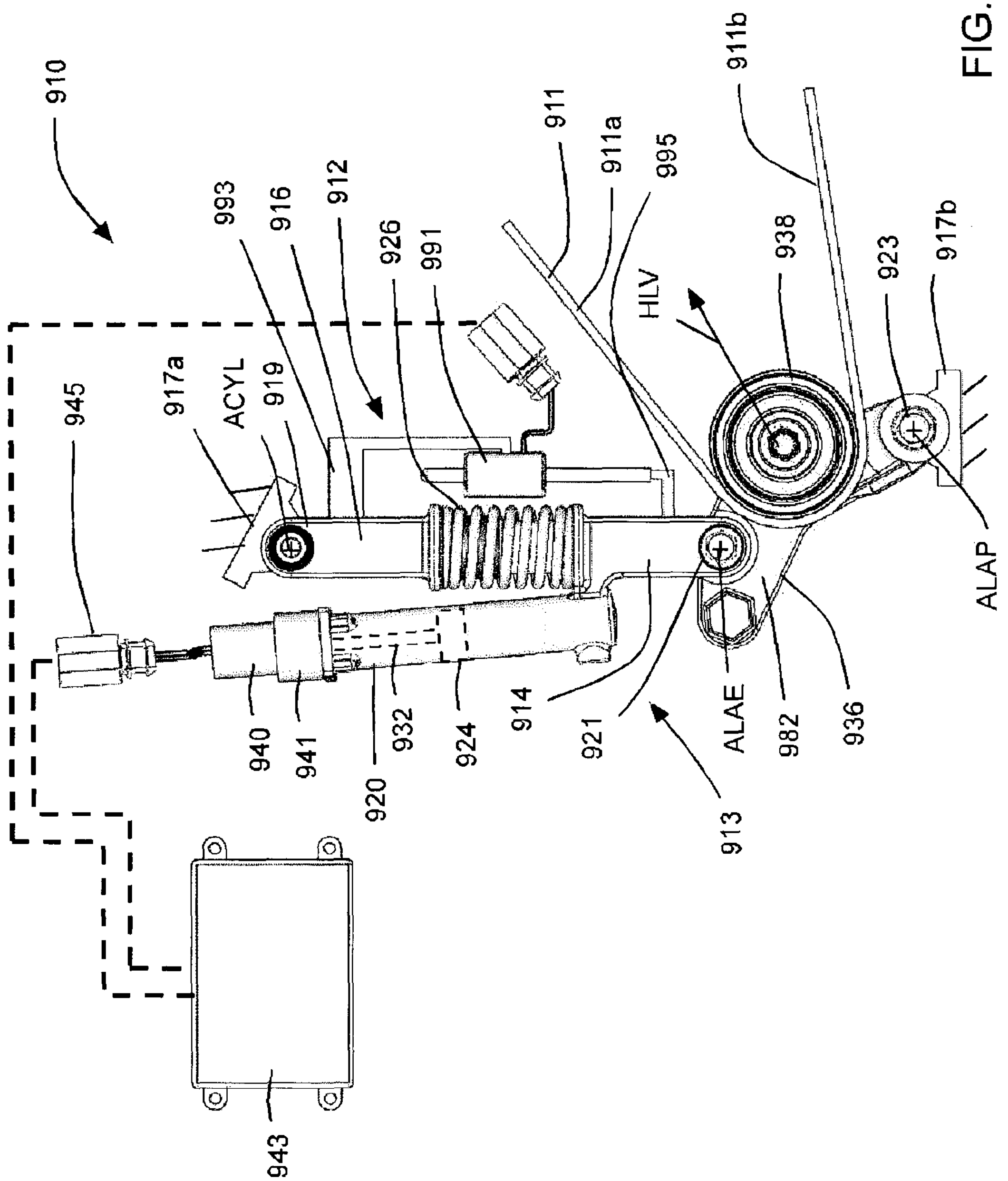
910
993
916
912
926
991
911
911a
995
911b
938
923
917b
HLV
917a
ACYL
919
945
ALAP
940
941
920
932
924
914
921
913
ALAE
982
936
943

FIG. 39

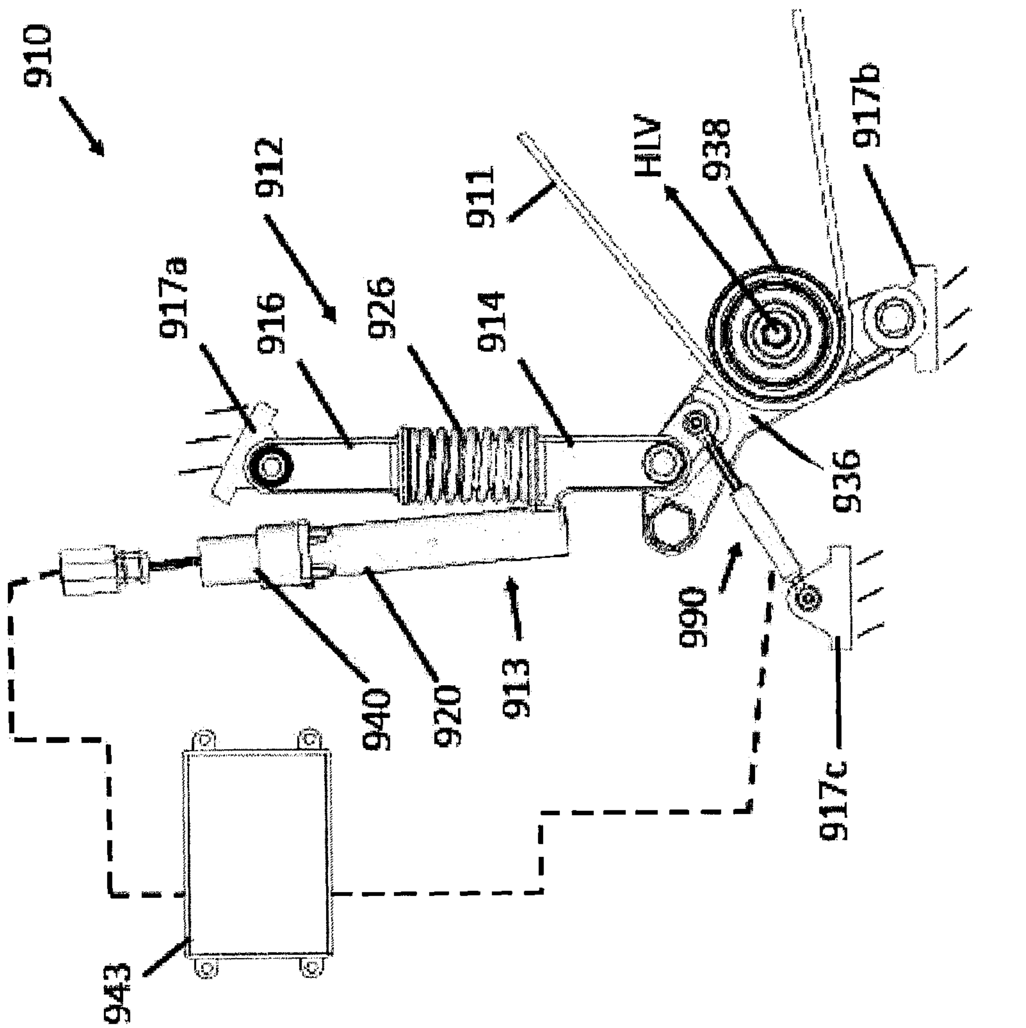

Fig. 40
WIRELESS PRESSURE SENSOR
LINEAR POSITION TRANSDUCER

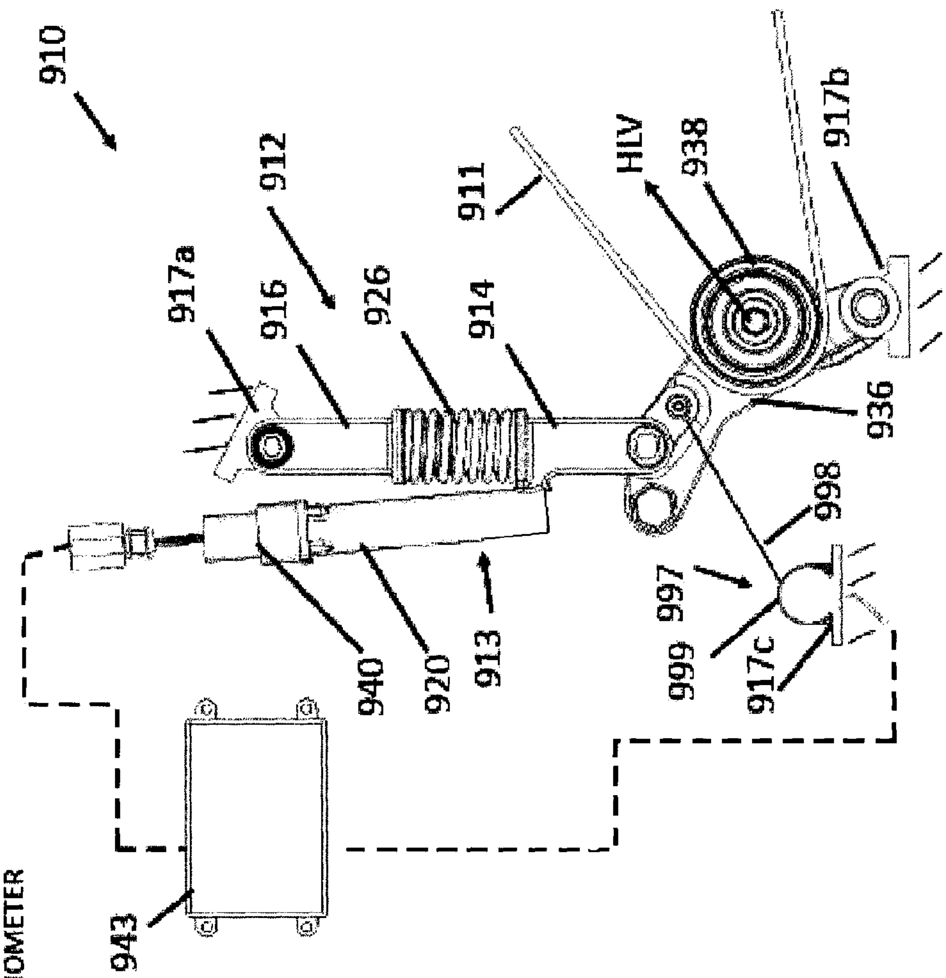

Fig. 41
WIRELESS PRESSURE SENSOR
STRING POTENTIOMETER

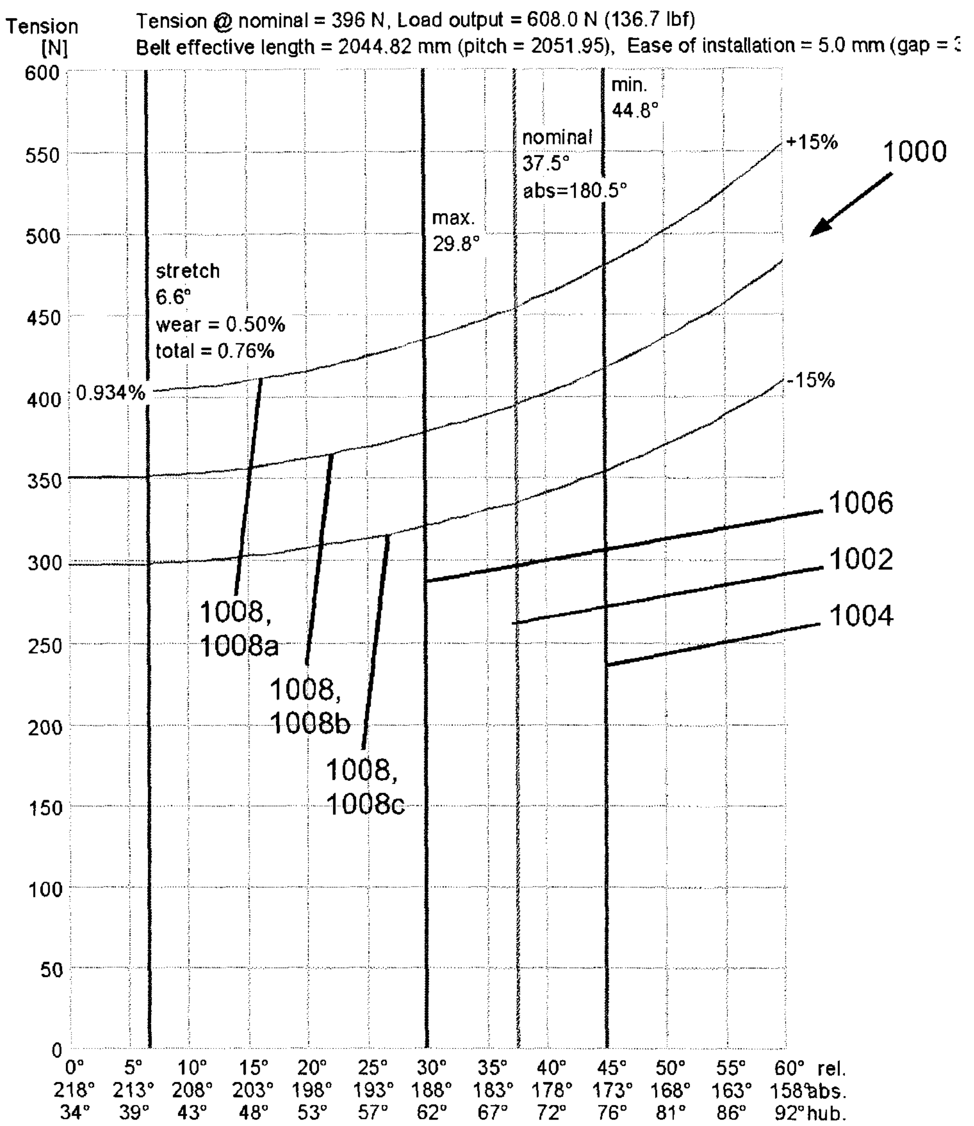
Tension [N]
Tension @ nominal = 396 N, Load output = 608.0 N (136.7 lbf)
Belt effective length = 2044.82 mm (pitch = 2051.95), Ease of installation = 5.0 mm (gap = 3
600
550
500
450
400
350
300
250
200
150
100
50
0
min. 44.8°
nominal 37.5° abs=180.5°
max. 29.8°
stretch 6.6° wear = 0.50% total = 0.76%
0.934%
+15%
-15%
1000
1006
1002
1004
1008, 1008a
1008, 1008b
1008, 1008c
0° 5° 10° 15° 20° 25° 30° 35° 40° 45° 50° 55° 60° rel.
218° 213° 208° 203° 198° 193° 188° 183° 178° 173° 168° 163° 158° abs.
34° 39° 43° 48° 53° 57° 62° 67° 72° 76° 81° 86° 92° hub.

FIG 42

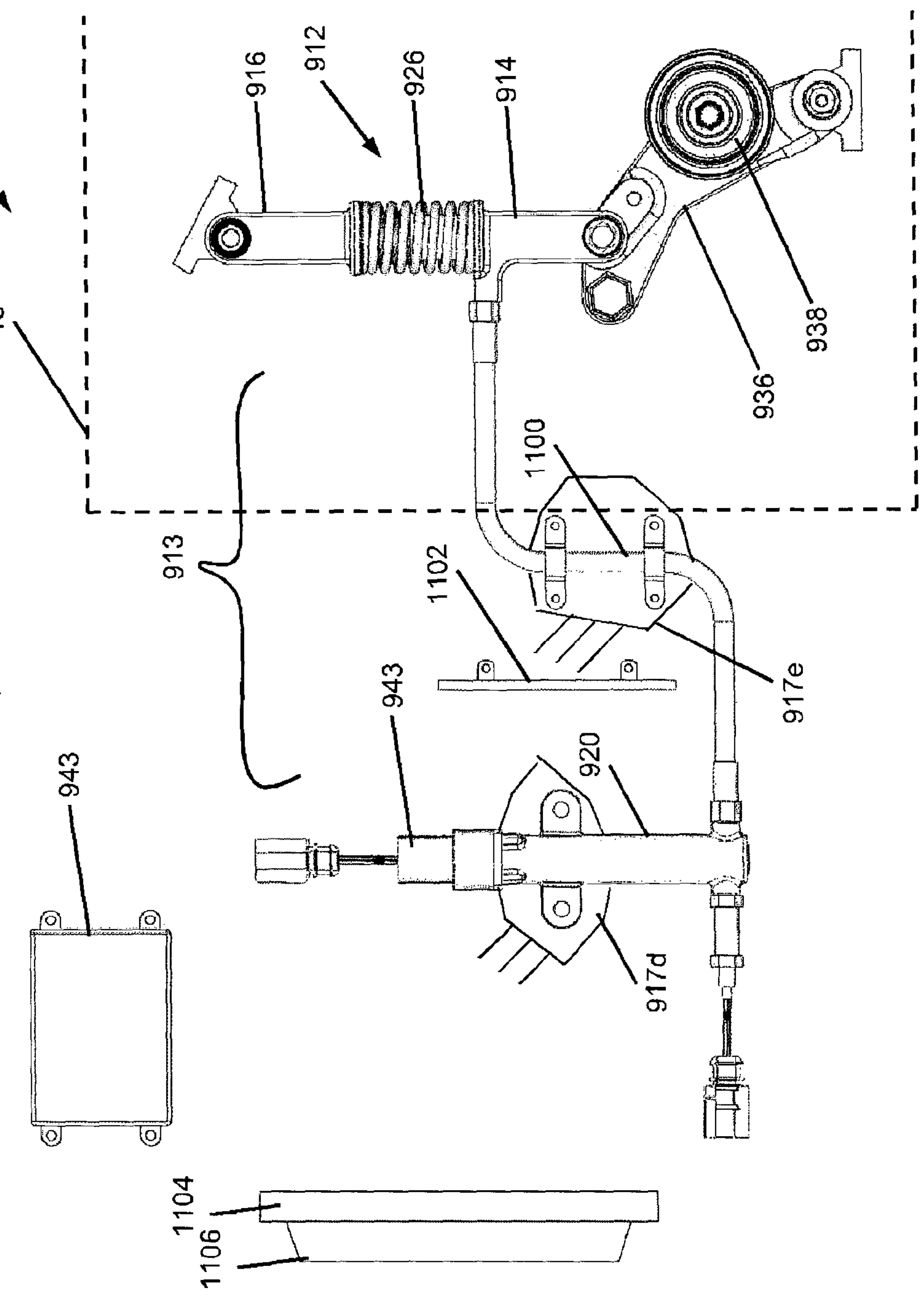

Fig. 43
HYDRAULIC RESERVOIR TUBE MOUNTED REMOTELY WAY FROM ADT TENSIONER STRUT CYLINDER VIA FLEXIABLE HYDRAULIC HOSE/TUBING

INTELLIGENT BELT DRIVE SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application No. 61/531,021, filed Sep. 5, 2011, U.S. Provisional Patent Application No. 61/584,314, filed Jan. 9, 2012, U.S. Provisional Patent Application No. 61/588,076, filed Jan. 18, 2012 and PCT application PCT/CA2011/001032, filed Sep. 12, 2011, all of which are incorporated herein by reference in their entirety.

FIELD

The present disclosure relates to tensioners for tensioning engine driven elements such as timing belts, timing chains and accessory drive belts. In particular, the present invention is directed to belt tensioners that have the capability to actively adjust the belt tension in the belt.

BACKGROUND

Tensioners for timing belts, timing chains and accessory drive belts are well known. Some tensioners are adjustable in terms of the amount of tension is generated in the belt during operation of the engine. Such tensioners react to certain sensed conditions that indicate a potential for, or occurrence of, belt slip. While such systems may reduce the frequency of belt slip, they are, by design, inherently permitting some belt slip to occur. In those systems that sense the actual occurrence of belt slip, belt slip has already necessarily occurred before the tensioner will increase belt tension. In systems where the conditions for belt slip are sensed, the conditions that create the potential for belt slip must already occur for them to be sensed by the tensioner, which inherently means therefore that belt slip can occur before the tensioner has reacted to increase belt tension.

While these systems have some advantage in terms of reducing the frequency of belt slip, they still permit some belt slip to occur, which may be detrimental to the belt, to certain accessories driven by the belt, and to the perception of quality of a person hearing the chirp that can accompany belt slip.

Furthermore, the tension adjustment mechanisms employed by such tensioning systems may be expensive, and/or unreliable.

It would be beneficial to provide a tensioning system that has at least partially addresses one or more of these problems.

SUMMARY

In one aspect, a tensioner is provided that is capable of precognitively anticipating when it is desirable to increase the tension in a belt or other endless drive element so as to prevent belt slip prior to events that would raise the risk of it.

In another aspect, a system and method for controlling a tensioner that has adjustable tension, in such a way as to avoid the tendency of the tensioner to cycle between high and low tension settings.

In another aspect, the invention relates to the use of one or more of the parameters described herein for the purpose of preventing belt slip.

In another aspect the invention relates to the embodiments of tensioners shown and described herein.

In another aspect, a tensioner is provided that incorporates a hydraulic cylinder to adjust the tension in a belt or other endless drive member is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects will be more readily appreciated having reference to the drawings, wherein:

FIGS. **1**_a_-**14**_b_ are views of tensioners that include systems for mechanically and electrically driving changes in the tension of an endless drive member;

FIGS. **15**-**43** are views of tensioners that include systems that incorporate at least a fluid actuated cylinder for driving changes in the tension of an endless drive member.

Some aspects of FIGS. **1**_a_-**14**_b_ are relevant to the tensioners shown in FIGS. **15**-**43**. For example some of the sensors shown in FIGS. **1**_a_-**14**_b_ can be incorporated on the tensioners shown in FIGS. **15**-**43**. Some aspects of FIGS. **15**-**43** are relevant to the tensioners shown in FIGS. **1**_a_-**14**_b_.

DETAILED DESCRIPTION OF EMBODIMENTS

In this specification and in the claims, the use of the article "a", "an", or "the" in reference to an item is not intended to exclude the possibility of including a plurality of the item in some embodiments. It will be apparent to one skilled in the art in at least some instances in this specification and the attached claims that it would be possible to include a plurality of the item in at least some embodiments.

Reference is made to FIG. **1**_a_, which shows a crankshaft **10** from an engine **13** from a vehicle. The crankshaft **10** has a crankshaft pulley **12** thereon. The crankshaft pulley **12** drives one or more vehicle accessories via a belt **14**. The accessories may include an alternator **16**, an air conditioning compressor **18**, a water pump (not shown in FIG. **1**_a_), a power steering pump (not shown) and/or any other suitable accessory. Each of the driven accessories has a shaft, and a pulley that is connectable and disconnectable from the shaft via a clutch. The alternator shaft, clutch and pulley are shown at **50**, **52** and **54** respectively. The air conditioning compressor shaft, clutch and pulley are shown at **56**, **58** and **60** respectively. This permits each of the accessories to be shut off when not needed even though the belt **14** itself is still being driven by the crankshaft **10**.

Providing at least a certain amount of tension in the belt **14** is beneficial in that it reduces the amount of slip that can occur between the belt **14** and the driven accessories or even between the belt and the crankshaft **10**. However, providing an unnecessarily high tension in the belt **14** has many detrimental effects. For example, it causes more power from the engine **13** to be consumed in driving the accessories, leaving less power for use in driving the vehicle. Thus, to achieve a particular level of performance from the vehicle, a greater amount of fuel would be consumed than would be consumed if the power loss were smaller. Additionally, a high belt tension generates greater hub loads on the pulleys for the driven accessories, which necessitates the use of relatively larger shafts on the accessories, larger bearings to support the shafts, heavier brackets to hold the accessories in place, all of which add to the weight of the vehicle and thereby negatively impact fuel economy for the vehicle.

A belt tensioner **20** is shown which keeps the belt **14** tensioned so as to reduce belt slip, and to keep the belt on the pulleys of the crankshaft **10** and accessories. The tensioner **20** includes a tensioner pulley **22** which engages the belt **14**, a tensioner arm **24** which holds the tensioner pulley **22**, a tensioner biasing member **26** for biasing the tensioner arm **24** towards a free arm stop position (the position the arm **24** would reach if it was not pressing into the belt **14**), which would represent the position of reduced stored mechanical potential energy within the elastomeric biasing spring within the tensioner travel range, and a load stop position (the position the arm **24** would reach if the arm **24** were pushed all the way throughout its range of travel away from the free arm stop position), which would represent the position of increased stored mechanical potential energy within the elastomeric biasing spring within the tensioner travel range. The tensioner **20** further includes a tensioner actuator **28** which is operatively connected to the tensioner pulley **22** and tensioner arm **24** to move the pulley **22** and arm **24** between the free arm stop and load stop positions. The tensioner **20** may include structure that dampens its motion.

The belt tensioner **20** may have any suitable structure that provides the aforementioned capabilities. For example, the arm **24** may telescope linearly and may be biased outwards by a compression spring, which may be the tensioner biasing member **26**. The first end of the spring **26** engages the arm **24**, and a second end of the spring **24** engages a base **30**. The base **30** is movable along the arm **24** by the tensioner actuator **28**. For example, the tensioner actuator **28** may include an electric motor that turns a lead screw (not shown), whose rotation drives a traveler (also not shown) forwards or backwards. The base **30** is connected to the traveler and moves therewith. The lead screw may be hollow and the arm **24** may telescope outwards from it. Thus, the arm **24** is movable independently from the base **30** and from the lead screw. The tensioner actuator **28** is controllable to drive the base **30** forwards or backwards. Driving the base **30** forwards increases the amount of compression in the spring **26** thereby increasing the biasing force exerted by the spring **26** on the arm **24** and in turn on the pulley **22** in the free arm stop direction, thereby increasing the tensioning force exerted by they pulley on the belt **14**. Driving the base **30** backwards decreases the amount of compression in the spring **26**, thereby reducing the tensioning force exerted by the pulley **22** in the free arm stop direction on the belt **14**. The biasing force of the spring **26** may be referred to as an actuator force since the actuator **28** controls the magnitude of this force. The tensioner actuator **28** may have any suitable motive means with which to drive the movement of the base **30** instead of an electric motor, such as, for example, pneumatic or hydraulic pressure, a shape memory metal actuator, or some other means.

In an alternative embodiment shown in FIG. **1***b*, the tensioner arm **24** is pivotable about a tensioner arm pivot axis. The tensioner biasing member may be a torsion spring which is engaged at a first end with the arm to bias the arm towards the free arm stop. The second end of the torsion spring may be engaged with the tensioner actuator **28** which moves the second end of the spring to increase or decrease the biasing force of the spring on the tensioner arm **24** and therefore the tensioning force of the pulley **22** on the belt **14**.

Examples of suitable tensioner structures may be found in PCT publication number, WO2010/094127A1, and in U.S. Provisional patent applications 61/382,892, 61/381,929, and 61/391,266, all of which are hereby incorporated by reference. Examples of suitable actuators that can be used to drive the second end of the torsion spring may be found in U.S. Pat. Nos. 3,954,016, 4,131,306, 4,674,781, 4,850,466, 4,885,954, 4,893,704, 5,338,076, 5,634,676, 5,862,903 and 5,983,739, all of which are hereby incorporated by reference.

In reference to the tensioner embodiment shown in FIG. **1***b*, the graph shown in FIG. **1***c* illustrates the relationship between the length of the belt **14**, the force applied by the spring **26** on the tensioner arm **24** (shown at **90**), and the resulting torque applied by the tensioner arm **24** on the belt **14** (shown at **92**). The nominal belt length is shown at **96**, and with plus and minus tolerances at **98***a* and **98***b*. In general throughout this disclosure, when it is stated that the tensioner arm is driven into the belt **14**, is engaged with the belt **14**, applies torque to the belt **14** or the like, it will be understood that it is actually acting on the belt **14** through the pulley. As the belt stretches, the arm **24** rotates progressively further as a result of the spring force acting on it. However, the spring force progressively decreases as the arm **24** rotates during belt stretch, since the spring **26** is progressively unwinding towards its rest position. Also, the rotation of the arm **24** changes the geometric (i.e. angular) relationship of the arm **24** to the applied hubload of the pulley **22** on the belt **14**. As a result, even though the spring force may be decreasing linearly with rotation of the arm **24**, the torque applied to the belt **14** varies non-linearly (sinusoidally in a typical configuration) with rotation of the arm **24**. The result of these changes is shown in the graph in FIG. **1***d*, which illustrates the relationship between the belt tension generated by the tensioner, as a function of belt length. In theory it would be advantageous to be able to apply a certain target tension to the belt through the tensioner, which was constant regardless of belt length, and hence regardless of the angular position of the tensioner arm **24**. This target tension is shown at **100** in FIG. **1***d*. However, when using a torsion spring such as spring **26**, and a rotating tensioner arm **24**, the curve shown at **102** is what results. A line indicating the nominal length of the belt **14** is shown at **96**. The tensioner **20** is configured so that its response curve **102** to changes in belt length, even though non-linear, somewhat match up closely with the 'target' tension line **100**.

In a typical tensioner of the prior art, the response curve applied by the tensioner is somewhat fixed in the sense that the tension applied by the tensioner on the belt **14** changes based on belt length only (ignoring dynamic issues relating to belt flutter and the like, which can temporarily affect the response of the tensioner). As a result, such tensioners are typically configured to apply a relatively high target tension to the belt because they must ensure that the belt has sufficient tension in it in the worst case scenarios (e.g. under harsh operating conditions where the belt is wet, where the load on the belt is high due to operation of all of the accessories driven by the belt, due to high rates of change of the engine rpm, and the like). However, in reality these worst-case scenarios are not the norm, and under most operating conditions, the belt tension that is applied by these prior art tensioners is needlessly high. This constant state of high tension in the belt unfortunately results in a needless consumption of power, overdesign of bearings and the like for pulleys that are engaged with the belt, potentially shortened operating life of the belt, increased emissions from the vehicle, and other disadvantages.

The tensioner **20** is capable, however, of adjusting the tension in the belt **14** so that when the need arises for high tension, the tensioner **20** is capable of increasing the tensioning force applied to the belt **14**, thereby increasing the tension in the belt **14**. This can result, in some embodiments in a shift upwards of the tension response curve shown in FIG. **1***d*, from the curve **102**, to the dashed line curve shown at **106**. The curve **106** need not match the shape of the curve **102**. Moreover the effective spring constant applicable to the tensioner **20** when in a 'high tension' mode as represented by the curve **106** is not critical. Thus, the shape of the curve **106** is not particularly critical. It is important mainly that the tension applied to the belt **14** is sufficiently high to prevent belt slip under the particular conditions that triggered the tensioner **20** to raise the tension, while ensuring that the tension applied to the belt **14** is not so high as to damage the belt **14** or the components engaged with the belt **14** (e.g. the pulleys driving and driven by the belt **14**).

A primary purpose of providing sufficient tension in the belt **14** is to prevent belt slip, which is a condition in which the linear speed of the belt on a pulley is different than the linear speed of the periphery of the pulley itself (that is where the slipping occurs). This slipping is problematic for many reasons. One reason is that the slipping is inefficient, in the sense that the movement of the belt is not resulting in as much rotation as would be desired of the accessory driven by the pulley. Another reason is that the slipping can be audible in some circumstances, which can result in the impression on the part of the vehicle owner or passersby that there is a quality issue with the vehicle.

It is beneficial for the tensioner **20** to be able to determine if belt slip is taking place. To do this, the tensioner **20** may determine the linear speed of the belt **14**, and the linear speed of one or more of the pulleys from accessories that are driven by the belt **14**. The linear speed of the belt **14** may be determined by determining the linear speed of a pulley that is driven by the belt, but that relatively little rotational inertia or more broadly, resistance to rotation, associated with it. An example of such a pulley is the pulley **22** on the tensioner **20**. Such a pulley typically has no belt slip associated with it and therefore provides a relatively accurate value for the speed of the belt **14** during operation of the belt tensioning system. To provide a value for the speed of rotation of the pulley **22** any suitable means may be used. For example, a sensor trigger, such as a magnet or a metal target, shown at **70**, may be placed in the pulley as shown in FIG. **2***a*, and a suitable sensor **72**, such as a Hall effect sensor may be positioned in the tensioner arm **24**. A plurality of the magnets or metal targets **70** may be spaced equally from each other about a circle at some radius on the pulley **22**. Alternatively, as shown in FIG. **2***b*, a plurality of sensor triggers, such as teeth, protrusions, or conversely, recesses, could be incorporated into the pulley **22** and a suitable sensor **72**, such as a Hall effect sensor, could be mounted to a stationary element, such as a base mounting to sense the passage of the sensor triggers **70**.

The pulley **22** may be machined from a suitable metal, or spun from metal sheet into a flanged configuration as shown. One or more teeth, recesses, protrusions, targets or other sensor triggers **70** may be machined into whichever edge of the pulley passes overtop of the sensor **72**. As an example, the pulley may be machined from magnetic steel.

The sensor **72** is positioned to be able to detect the passing of the sensor triggers. For balance purposes, should the pulley be required to spin at very high RPM, it may be beneficial to have at least two sensor triggers **70** that are equally spaced apart on the pulley flange so as to balance the inertia of the targets when the pulley **22** spins at high speed.

As more sensor targets **70** are provided at equal spacings on the pulley edge the balance of the pulley **22** improves. Thus for applications where the pulley's RPM is high, it is more beneficial to configure the pulley **22** with an increased number of sensor triggers **70** to improve its dynamic balance. As the number of teeth (or more generally, sensor triggers **70**) increases, the accuracy of the determined RPM increases in addition to the improvement in balance. As shown in FIG. **2***b* the pulley **22** may have any suitable number of sensor triggers **70**, such as, **10** sensor triggers.

The sensor **72** may include a processor which counts the passage the sensor triggers **70** overhead, and thereby determine the instantaneous RPM of the pulley **22**. Once the RPM of the pulley **22** is known, the belt speed can be determined with high accuracy.

The pulley **22** may be used for determining the belt speed as described above, provided that there is sufficient belt wrap on the pulley **22**. Additionally, in some circumstances there may not be sufficient room to install the sensor **72** or the triggers **70** on the tensioner arm **24** or pulley **22**. If any of these conditions exist such that the belt speed cannot be determined using the tensioner **20**, a separate idler pulley can be installed in a separate location in engagement with the belt **14** wherein a sufficient amount of belt wrap is provided.

An engine controller shown at **32** is provided in the vehicle and controls the operation of the engine **13** and the accessories. The engine controller **32** may be referred to as the vehicle control unit **32**. The vehicle control unit **32** may receive sensor data from several sources, including signals from a speed sensor on the crankshaft **10** that indicates the speed of rotation of the crankshaft **10**. The tensioning system, which includes the tensioner **20**, may further include a tensioning system controller shown at **34**. The tensioning system controller **34** controls the operation of the tensioner actuator **28**. The tensioning system controller **34** additionally may receive signals from one or more other components indicative of the states of those components. For example, the tensioning system controller **34** may receive signals indicative of the crankshaft speed, the alternator voltage output, the alternator speed, the alternator temperature, the position of the tensioner biasing member **24**, and the speed of the tensioner pulley **22** (as described above, using one or more sensor triggers **70** and sensor **72**). The controller **34** can determine if any slip is occurring at any of the pulleys for the crankshaft **10**, the alternator **16** and the compressor **18** based on any detected differences between their actual measured speed and the speed they should be rotating at based on their pulley diameter as compared to that of the tensioner pulley **22**. If any slip is detected, or if the slip detected on any pulley exceeds an upper threshold value, such as about 3% to about 4%, the controller **34** may increase the actuator force so as to increase belt tension, so as to reduce or completely eliminate the slip. The increase in the actuator force may be by a discrete amount such as 25N after which the slip is rechecked to determine if it is below the upper threshold value. Alternatively, the increase in the actuator force may be continuous with continuous determination of the slip being made by the controller **34**. In either case the controller **34** may stop increasing the tension once it determines that the slip is below the threshold value for all pulleys. Conversely, if the slip detected on all the pulleys is below a lower threshold value (which may be, for example, about 2%), then the controller may decrease the actuator force so as to reduce belt tension in order to provide improved fuel economy and reduce power losses. The decrease may be continuous, or it may be in discrete amounts.

The tensioning system controller **34** may also receive signals from the vehicle control unit **32** indicating what action the vehicle control unit **32** is about to take. For example, the vehicle control unit **32** may indicate to the tensioning system controller **34** that it is about to turn on the air conditioning compressor **18**. As a result, the tensioning system controller **34** may be capable of using the incoming signals to determine that belt slip is about to occur, or that the load on the belt **14** is about to increase. In case of one of these determinations the tensioning system controller **34** may pre-emptively increase the actuator force on the tensioner pulley **22** so as to increase the belt tension prior to these events occurring. As a result, the belt slip is reduced (or even prevented).

In another scenario, where the vehicle is off, as the driver of the vehicle approaches the vehicle, the tensioning system controller **34** may sense the presence of the key fob, similar to the systems that sense the presence of the key fob for the purpose of unlocking the vehicle's doors in some luxury cars today. Instead of the controller **34** directly sensing the presence of the key fob, the vehicle may communicate to the controller **34** that some other system (such as the system responsible for unlocking the vehicle doors when sensing the presence of the key fob in vehicle so equipped). Alternatively, the tensioning system controller **34** may detect that the key fob was used to unlock the driver's door (by a user pressing an 'unlock' button on the key fob). As a result, the tensioning system controller **34** may determine that the vehicle's engine **13** may be started imminently. Engine startup introduces a relatively high load on the belt **14**, and can cause belt slip in a belt that is under too little tension. In order to reduce the likelihood of belt slip, the tensioning system controller **34** may increase the actuator force on the tensioner pulley **22** prior to engine startup so as to prevent belt slip from occurring.

Instead of sensing the key fob, a less expensive option may be for the controller **34** to be programmed to increase the belt tension at certain times of the day on certain days. For example, the controller **34** may be equipped with a clock or may be programmed to determine the time and date from some other subsystem in the vehicle such as a GPS receiver, and may be programmed to detect patterns in terms of the times of day that the vehicle is driven. For example, the controller **34** may determine that, over the previous 30 days (or over any other suitable number of days) the vehicle has been started up on weekdays (i.e. Monday to Friday) at between 7:45 am and 7:55 am over 90% of the time and never earlier than 7:37 am. The controller **34** may be further programmed to use this data to determine a time of day to increase the belt tension in anticipation that the engine will shortly be started. For example, the controller **34** may increase the belt tension at 7:43 am every weekday, or, for example, at 7:35 am every weekday. After increasing the tension in the belt **14**, the controller **34** may enter, or return to, a sleep mode until it is awakened by some input, such as by the detection of the vehicle being started. In addition, time of day and date information can be used to predict the need for high tension in the belt **14** in other ways. For example, in embodiments where a humidity sensor or a moisture sensor are not present, the controller **34** may determine that, based on the time of day (e.g. early morning) and the date (e.g. early fall), there is an increased likelihood of belt slippage from dew on the belt **14**. As a result, the controller **34** may be programmed to keep the belt **14** under high tension for a selected period of time after engine start up to allow the engine to warm up and the dew to evaporate. Conversely, in the mid-afternoon on a summer day, the controller **34** may be programmed to keep the belt **14** under high tension for a shorter selected period of time after engine start up due to an expectation that there is no dew on the belt **14**.

Another example is where the controller **34** receives data from an ABS system and/or a traction control system to determine whether there is repeated pending wheel lockup or pending wheel slip during a particular use of the vehicle. This data, optionally in combination with temperature data and/or time and date data, can be used to infer that there is snow on the ground, or, depending on the sensed temperature, to infer that there may be slush or water on the ground. If snow, slush or water is inferred to be on the ground, then the controller **34** may determine that the belt tension should be increased due to the potential for the belt **14** to become wet from kickup or some other reason during driving, for example. If the temperature is below a selected level, the controller **34** may determine that the belt **14** is likely to be relatively stiff, and possibly loose. Also, at low temperature, grease or other lubricants used to facilitate the rotation of bearings and the like tends to 'stiffen' thereby increasing the resistance to turning of any rotating components. As a result, below a certain temperature, the controller **34** may therefore increase belt tension.

In another example, the tensioning system controller **34** may receive a signal that the humidity is high from a sensor such as a humidity sensor. This can be an indication that it is raining, or that the vehicle is in some sort of situation where the belt **14** is potentially wet. When the belt **14** is wet, it will be understood that there is an increased likelihood of belt slip at any given belt tension, as compared to a dry belt **14**. When the tensioning system controller **34** determines that the humidity is high, the tensioning system controller **34** may automatically increase the actuator force on the pulley **34** so as to reduce the potential for belt slip. In a scenario where the tensioning system controller **34** has determined that a particular level belt tension is suitable for a particular situation, the tensioning system controller **34** may augment the belt tension to a higher level in a situation where it detects high humidity. An example of a suitable humidity sensor is an HIH series humidity sensor provided by Honeywell International Inc. Instead of, or in addition to, a humidity sensor, the tensioning system may include some other sensing means to detect a wet belt **14** or the potential for a wet belt **14**, to trigger it to increase the belt tension. For example, a temperature sensor positioned to detect the temperature in the engine bay may be used, in conjunction with an ambient temperature sensor and a humidity sensor, to detect the potential for a wet belt in certain situations. A humidity sensor that is configured to determine relative humidity in the engine bay, would include a temperature sensor that would be positioned to detect the temperature in the engine bay. For example, when a vehicle is kept in a cool location such as in a garage or an underground parking lot, and is then started up and taken out on a hot day, there is the potential for water vapour in the air to condense on many components of the relatively cool vehicle including the accessory drive belt and the pulleys it engages, which can lead to belt slip or belt chirp. To handle this, the tensioning system controller **34** may be programmed to sense when the temperature in the engine bay is lower than the ambient temperature by more than a selected amount while the humidity is above a selected level, and if so, to increase the belt tension to a selected high tension setting. After the engine bay has warmed up (e.g. by operation of the engine) the controller **34** may determine that there is no longer the potential for belt slip or belt chirp and may accordingly reduce the belt tension.

In order to determine whether it is raining, the controller **34** may receive signals from both the humidity sensor, and from the windshield wiper system. If the humidity is high and the windshield wipers are on, then the controller **34** may determine that it is raining. If the humidity is high but the windshield wipers are off, then the controller **34** may determine that it is not raining. If the humidity is not high but the windshield wipers are on, the controller may determine that it is not raining. As an example, the windshield wipers may have been put on for some other reason, such as to clean the windshield of dirt, snow or frost for example.

In yet another example, the tensioning system controller **34** may receive signals from the throttle sensor or from the vehicle control unit **32** that the driver is driving aggressively, and is repeatedly accelerating rapidly and/or is repeatedly letting off the throttle rapidly. In a less sophisticated embodiment, each time the driver accelerates (particularly if they accelerate hard), the tensioning system controller **34** will drive the actuator force up to increase the belt tension to prevent slip, and each time the driver suddenly releases the throttle, the tensioning system controller **34** will drive the actuator force down to decrease the belt tension since high tension may be considered not necessary. It will be understood that driving the actuator **28** consumes energy. Repeatedly driving the actuator force up and down can in some situations consume as much or more power than is saved by the overall reduction in average belt tension, and can shorten the life of the tensioner actuator **28** and other components. In a more sophisticated embodiment, after a sufficient number of repetitions of these actions, the tensioning system controller **34** may determine that this driving behaviour is likely to continue and as a result, the tensioning system controller **34** may simply leave the tensioning force at a high setting, so as to prevent hunting of the actuator **28** to reduce and increase the tensioning force in an attempt to achieve a constantly moving or oscillating target. Once the tensioning system controller **34** detects that the driver's driving behavior has changed and he/she is no longer driving as aggressively for a sufficient period of time, the tensioning system controller **34** may decide to permit the reduction of the belt tension. There are several ways of determining whether the driver of the vehicle is driving aggressively. One way is to receive signals relating to the engine rpm. If the controller **34** determines that the engine rpm cycles between a level that is above a first, 'high' level and a level that is below a second, 'low' level then the controller may determine that the vehicle is being driven aggressively. A parameter that may also be used by the controller **34** for this determination is the cycle time. In other words, if the engine rpm reaches into the 'high' range (i.e. above the 'high' level) and then falls into the 'low' range (i.e. below the 'low' level) sufficiently slowly, the controller **34** may determine that the engine is not 'cycling' and that this does not constitute sufficiently aggressive driving to warrant leaving the tensioning force in a high tension setting. However, if the engine rpm cycles between the 'high' range and the 'low' range in relatively short periods of time, then the controller **34** may determine that the engine is cycling and that this does constitute a situation where leaving the tensioner in a high tension setting is warranted. It will be noted that even if the controller **34** uses signals from the throttle sensor, the controller **34** can still be said to be basing the determination of whether the engine is cycling on engine rpm since the signals from the throttle sensor can have a rough correlation to engine rpm.

Another way of using the engine rpm is for the controller **34** to use the rate of change of the engine rpm to determine whether or not to leave the tensioner at a high tension setting. If the rate of change of the engine rpm repeatedly exceeds a particular 'high' level then the controller **34** may determine that the engine is cycling and may leave the tensioner at a high tension setting regardless of the actual engine rpm reached.

The controller **34** may be programmed to store events where it has determined that the vehicle is being driven aggressively in a database and may additionally store other information related to the event, such as, for example, the time of day, or some type of identification information that identifies which driver is driving the vehicle. For example, upon entry into the vehicle, the driver may have pushed one of the seat position memory buttons. This seat position button identifies the driver of the vehicle as Driver #**2**. The controller **34** may store the driver identification in memory. In the event that the controller **34** determines that a cycling event occurred (or in general that an aggressive driving event occurred), the controller **34** may store that in its memory along with the driver identification information. If the controller **34** determines that this particular driver has too many instances of aggressive driving, the controller **34** may make changes to the criteria that would trigger the controller **34** to put the tensioner in a high tension setting whenever it senses that that driver is driving the vehicle. Another way that the vehicle may identify the driver is by the key fob. In some luxury vehicles today, the vehicle's controller is capable of distinguishing one key fob from another. The vehicle's controller uses this information to adjust the seats, mirrors and the like to each driver's preferences based on which key fob is sensed. Thus the controller **34** may be able to determine which driver is driving the vehicle based on which key fob is being sensed by the vehicle's sensors.

Further with respect to reducing the tendency of the tensioner actuator **28** to hunt continuously, the tensioning system controller **34** may be programmed to may raise or drop the belt tension by discrete amounts as opposed to continuously adjusting it to achieve the optimal belt tension for dynamic (i.e. continuously changing) conditions. The tensioning system controller **34** may be programmed for this to occur always, or alternatively it may be programmed for this to occur only under certain conditions, while permitting hunting (i.e. continuous adjustment of the belt tension) under other conditions. An example of the use of a discrete change in belt tension is in a situation where the tensioning system controller **34** detects a constantly increasing required belt tension. In such a scenario the tensioning system controller **34** may decide to increase the belt tension to a selected high setting and to leave it there for a period of time, (unless it becomes necessary to increase it further), instead of continuously adjusting the belt tension to just match the necessary tension for each instant of time.

In another scenario, the tensioning system controller **34** may detect a situation where the engine speed is low (i.e. below a selected threshold). Resonance can occur in the belt **14** depending on certain factors, such as the engine speed, the load on the belt **14** and the belt tension. Resonance can cause the belt **14** to flutter and can in some situations cause damage to or failure of the belt **14**. In particular, some belts that are proposed for use or are in use in vehicles today are relatively thinner than some belts previously used, which makes them even more prone to flutter. To inhibit this from occurring the tensioning system controller **34** may be programmed to detect situations where the engine speed and belt load would lead to an increased risk of resonance at a given belt tension, and to increase the belt tension so as to reduce the risk of belt flutter.

As shown in the examples described above, the tensioning system controller **34** may thus be capable of predicting situations in which belt slip may be imminent, or in which increased belt load may be imminent and may be able to control the belt tension before these events take place.

As described above, the tensioning system controller **34** can control the tensioning force by the pulley **22** on the belt **14** so as to reduce the belt tension where possible and to increase the belt tension when needed. This provides an overall improvement in fuel economy for the vehicle, as compared to a tensioner that is not controllable. However, this is, in some ways, a passive approach to reducing belt tension to improve fuel economy (which may be referred to as fuel efficiency). In some embodiments, the tensioning system controller **34** may take an active approach to reducing belt tension to improve fuel economy.

For example, the tensioning system controller **34** may be operatively connected to one or more of the alternator **16**, the air conditioning compressor **18** and any other accessories driven by the belt **14**. It will be understood that each of these accessories represents a load on the belt **14**, and each requires a certain amount of belt tension to operate without belt slip. By having two of these loads operate at the same time, as can commonly occur, the belt tension must be increased further in order to reduce the likelihood of slip. In an effort to reduce the maximum belt tension required to be applied by the tensioner, the tensioning system controller **34** may in some situations cause a reduction in the load associated with one of the accessories, when permitting another of the accessories to operate. For example, the tensioning system controller **34** may determine that the alternator **16** need not operate at its highest voltage (which increases the amount of magnetic drag is associated with the alternator **16**) when the air conditioning compressor **18** is on. Thus, the tensioning system controller **34** may reduce the voltage of the alternator **16** at those times if possible, and may possibly shut off the alternator altogether. Similarly, the tensioning system controller **34** may reduce the refrigerant flow to the air conditioning compressor **18** (or may shut if off entirely) when it determines that the alternator **16** needs to run at high voltage. It will be noted that some alternator types (e.g. some modern high efficiency alternators) have a relatively high amount of drag associated with them in cold weather. This is due, at least in part, in some circumstances to the close tolerances that exist between the rotating and stationary components of such alternators. In cold weather, differential amounts of shrinkage of some components relative to each other can increase the amount of rotational friction that exists until the alternator warms up. Furthermore, when the vehicle sits idle (i.e. when the vehicle is off) for any period of time (even overnight) during cold weather, the vehicle's battery can lose charge relatively quickly, thereby causing the alternator **16** to operate at high load at vehicle startup as it attempts to charge the battery. As such, the tensioning system controller **34** may prevent the alternator **16** from operating during startup of the engine **13** in cold weather since engine startup already introduces a high belt load which implies a raised belt tension. Once the engine **13** has started up and the belt tension necessary to prevent slip is reduced, the tensioning system controller **34** may permit the alternator **16** to start up. In some embodiments, the controller **34** may prevent alternator **16** from operating until the temperature of the alternator **16** reaches above a selected temperature. A temperature sensor that is directly responsible for sensing the temperature of the alternator **16** may be provided for informing the controller **34** of the alternator temperature. If it is determined that the alternator **16** is needed to operate but is below a selected temperature, the controller **34** may put the tensioner at a high tension setting prior to start up of the alternator. The selected temperature below which the alternator **16** may be considered to be cold may be for example, less than or equal to about −20 degrees C. Optionally, this condition (the low alternator temperature) may override other logic used by the controller **34** to modify belt tension. In other words, the controller **34** may be programmed to generate a high belt tension whenever it detects that the alternator temperature is below the threshold value (assuming that alternator operation itself is needed), and to hold the high belt tension until the alternator temperature rises above a second threshold value, such as, for example, +20 degrees C.

With respect to the alternator **16**, it is beneficial for the controller **34** to be able to estimate the torque needed to drive the alternator **16** in order to determine whether to change the belt tension. The alternator torque depends on several factors, including voltage, current and speed. These values can be mapped to estimate torque quickly and easily without significant computational requirements. The controller **34** can use this estimate to determine what belt tension is suitable.

It will be noted that the operative connection between the tensioning system controller **34** and the accessories may not be a direct one. For example, the tensioning system controller **34** may send instructions to the vehicle control unit **32** to stop or prevent operation of the alternator **16**, and the vehicle control unit **32** may determine whether this is possible. For example, the vehicle control unit **32** may determine that it is not possible due to a critically low state of charge of the vehicle battery (not shown). In such an instance, the vehicle control unit **32** may send a signal back to the tensioning system controller **34** that it cannot stop, slow down or prevent operation of the alternator **16**, in which case the tensioning system controller **34** may drive up the tensioning force accordingly. Overall, however, by providing some control over the accessories, the tensioning system controller **34** may be able to reduce the number of times the tensioning force needs to be driven up to high levels. The number of times that the tensioning force reaches high levels directly impacts the size of the shafts, bearings and brackets required for the various components associated with the accessories, so that they are sufficiently robust to resist deformation and fatigue. Reducing the number of times that the tensioning force reaches high levels can therefore result in the use of relatively smaller shafts, smaller and/or lighter-duty bearings, and lighter brackets. This reduction in weight of the components in turn results in an increase in fuel efficiency for the vehicle, and reduces rotational drag associated with the accessories which can result in a further increase in fuel efficiency for the vehicle.

Instead of sending instructions to the vehicle control unit **32**, it is alternatively possible for the tensioning system controller **34** to directly send commands to one or more of the accessories. However, the vehicle control unit **32** may also be directly or indirectly operatively connected to the accessories, and it may issue overriding commands to the tensioning system controller **34** under certain conditions which prevent the tensioning system controller **34** from interfering with the vehicle control unit's operation of the accessories.

The tensioning system controller **34** may receive signals from one or more components that are indicative of the current belt tension so that the tensioning system controller **34** can determine if the current belt tension is suitable or not for the current set of conditions. The signals may be from a position sensor that indicates the position of the second end of the tensioner spring, which gives an indication of the tensioning force exerted by the pulley **22** on the belt **14**. The position sensor could be a simple Hall-effect sensor which would send a signal proportionate to the distance between the sensor and the end of the spring. A suitable Hall-effect sensor could be a Honeywell SS 520 sensor, supplied by Honeywell International, whose headquarters are in Morristown, N.J., USA. Alternatively other more precise position sensing devices could be used, albeit at greater cost. Alternatively, the belt tensioning system may include other, more sophisticated devices, such as, for example, a strain gauge on one or more accessory shafts along with associated electronics for conditioning and signal amplification. Such devices are typically relatively high cost however. Such a device is described in U.S. Pat. No. 6,216,547 which is hereby incorporated by reference.

While the tensioning system controller **34** is shown as a separate device from the vehicle control unit **32**, it is possible to provide the equivalent of the tensioning system controller **34** within the vehicle control unit **32** itself. In other words the tensioning system controller **34** could be a program module that resides in memory along with the program module that makes up the vehicle control unit **32**. For the purposes of the claims provided below, however, the tensioning system controller **34** and the vehicle control unit **32** may nonetheless be considered to be separate elements regardless of whether they share hardware or even some software elements. The term 'controller' in reference to control system **34** is intended to be interpreted broadly so as to cover embodiments wherein there is a single control unit, and embodiments wherein there are multiple control units that control the operation of the tensioner **20**. For the purposes of this disclosure the term 'controller' is to be considered synonymous with the term 'control system'.

In a particular embodiment shown in FIGS. **3***a* and **3***b*, the vehicle may be equipped with technology that shuts off the engine **13** temporarily in certain situations to reduce emissions and increase fuel efficiency. For example the vehicle control unit **32** may shut off the engine **13** when the vehicle stops at a stoplight. When this occurs it may still be desirable to continue operation of one or more of the belt driven accessories, such as the air conditioning compressor, for example. To achieve this, the crankshaft **10** may be equipped with a crankshaft clutch **38** through which it connects to the crankshaft pulley **12**. By disengaging the clutch **38** the belt **14** can now be driven without the engine **13** turning. The alternator **16** may in such an embodiment be an MGU (motor/generator unit) which can operate as a motor, drawing power from an electrical source such as the vehicle battery (not shown). The MGU **16** can then drive the belt and the other belt-driven accessories. Such a system is described in WO2008/113186A1, which is hereby incorporated by reference. It will be noted that in FIGS. **3***a* and **3***b*, only the components directly engaged with the belt **14** are shown, such as the crankshaft **10** and related components, the accessories and related components and the tensioner **20**. Also, a water pump is shown at **55** in FIGS. **3***a* and **3***b* as one of the accessories. The difference between the embodiments shown in FIG. **3***a* and the embodiment shown in FIG. **3***b* is that the tensioner **20** in FIG. **3***a* is a linear tensioner (as shown in FIG. **1***a*), and the tensioner **20** shown in FIG. **3***b* is a rotary tensioner (as shown in FIG. **1***b*).

In such an embodiment, the tensioning system controller **34** may receive a signal from the vehicle control unit **32** indicating that the engine **13** is being shut off and may be programmed to reduce the belt tension to a low level so as to reduce the belt load, thereby increasing the amount of time the battery can support rotation of the MGU **16**. As a further step to reducing the belt load the tensioning system controller **34** may also reduce the refrigerant flow to the air conditioning compressor **18** to a relatively low level so as to reduce the belt load associated with the compressor **18**.

Alternatively, if flow reduction is not possible, the tensioning system controller **34** may attempt to mimic the reduction or the throttling of the flow of fluid by intermittently cycling the air conditioning compressor clutch on and off in a controlled fashion via a PWM pulse width modulation control strategy, or PPM, whereby the cycle time off and the cycle time on may be varied to optimize both the power savings potential as well as the cooling potential within the passenger compartment.

In such an embodiment, the MGU **16** may also be used to start the engine **13** (referred to sometimes as a BAS (Belt Alternator Start) system, or a Belt-driven Starter Generator). To carry this out, the crankshaft clutch is engaged so that the crankshaft pulley **12** and the crankshaft **10** rotate together, and the MGU **16** drives the belt **14** in order to drive the crankshaft **10**, thereby replacing a traditional starter motor. However, it will be noted that the crankshaft pulley **12** is positioned on a first side (shown at **40**) of the MGU pulley **54**. When the MGU pulley **54** drives the belt **14**, the first side of the MGU pulley **54** is the slack side. Thus the belt tension on the first side **40** is relatively lower than the belt tension on the second side (shown at **44**) of the MGU pulley **54**. The lower belt tension introduces some potential for slip to occur between the belt **14** and the crankshaft pulley **12**. It is possible to add a tensioner for the belt span between the MGU pulley **54** and the crankshaft pulley **12**, however this is an expensive solution. In order to reduce the risk of slip when only one tensioner is provided (i.e. tensioner **20**) the tensioning system controller **34** may use the tensioner **20**, which, as can be seen is positioned between the crankshaft pulley **12** and the air conditioning compressor pulley **60**, to increase the belt tension to a very high level so as to drive up the tension in the belt span (or belt spans) between the crankshaft pulley **12** and the MGU pulley **54** so as to reduce the likelihood of slip during starting of the engine **13** using the MGU **16**. To assist in distributing the tension applied by the tensioner **20** throughout the belt **14** more evenly, one or more of the accessories may be shut off by the tensioning system controller **34** when the MGU **16** is used to start the engine **13**. Once the engine **13** has been started, the MGU **16** may revert back to an alternator, the belt tension may be reduced and whatever accessories were shut off may be started up again. Increasing the belt tension has been described as being applicable during startup of the engine **13** by the MGU **16**, while the tension has been described as being reduced by the controller **34** when the MGU **16** is driving the accessories. However, in a case where an accessory that is on the slack side of the MGU pulley **54** (e.g. the water pump **55**) is determined to be necessary to operate without slip, the tension in the belt **14** may be increased by the controller **34** to facilitate it.

While the MGU **16** has been described as driving the belt **14** to drive the other accessories and/or to start the engine **13**, it is alternatively possible for alternator **16** to be an alternator only, and for a separate electric motor to be provided for driving the accessories and/or to start the engine **13** via the belt **14**.

Many of the scenarios described above relate to the controller **34** detecting a situation where increased belt tension may be required to prevent slippage from occurring, it may be possible for the controller **34** to detect upcoming situations where low belt tension may be permitted. For example, after detecting that the belt **14** potentially had dew on it and increasing the belt tension accordingly to prevent slip, the controller **34** may set a fixed period of time for the increased belt tension to occur, and, in the absence of other reasons to keep the belt tension up, the controller **34** may be programmed to reduce the belt tension automatically at the end of the fixed period on the assumption that the belt **14** is dry at that point.

Some systems of the prior art may adjust belt tension based on a determination that the current conditions are conducive to belt slip. However, this inherently means that there is a period of time during which the conditions exist and where belt slippage could occur prior to the system increasing belt tension. By detecting the potential for such situations before they occur (i.e. precognitively), the controller **34** is able to increase the belt tension before the need for increased belt tension arises, thereby avoiding a situation where slippage has already occurred before the tensioning system has had a chance to react.

Many parameters have been described herein as being useful for use by the controller **34** to determine the appropriate tension setting for the tensioner. All of these parameters may be combined into a map that may be stored in the controller memory. The controller **34** would then determine all the necessary inputs based on signals from sensors, from the vehicle ECU, and/or from other sources, and may then use those inputs with the map to determine a tension to apply to the belt **14**, and/or a tensioner mode for the controller **34**. An example of a tensioner mode would be a situation where the controller **34** has determined that the tensioner is hunting and then holds the tensioner at a particular tension setting for a set period of time to prevent it from hunting. Another example of a tensioner mode would be a situation such as during startup of the vehicle, whereby the tensioner may simply leave the tensioner at a high tension setting for a selected period of time, regardless of what signals are coming from the various sources.

Reference is made to FIGS. **4***a*-**4***c* and **5***a*-**5***c*, which show a tensioner **200** with an example of a tension adjustment system in accordance with another embodiment of the present invention.

The tensioner **200** includes a hub **221** that mounts to the engine **13**, a tensioner arm **224** that is rotatably supported by an arm bushing **225** on the hub **221** for rotation about a hub axis between a free arm stop position and a load stop position, and which holds a tensioner pulley **222** for rotation about a pulley axis Ap, a tensioner biasing member **226** (which may be referred to as a spring **226** or a torsion spring **226**, but which could be any suitable type of biasing member) for biasing the tensioner arm **224** towards the free arm stop position, and a tensioner actuator **228** which is operatively connected to the tensioner pulley **222** and tensioner arm **224** to change the tensioning force applied by the tensioner arm **224** on the belt **14** through the pulley **222**.

In the embodiment shown in FIGS. **4***a*-**4***c* and **5***a*-**5***c*, the tensioner actuator **228** is made up of a motor **230**, in this instance with an integral gearbox, a worm **232**, a sector gear **234** driven by the worm **232**, and a spindle **236**. The worm **232** is supported on bushings **238** in a bracket **240** that is part of the hub **221**, and is driven by the motor **230**, which is controlled by the controller **34**. The worm **232** causes rotation of the sector gear **234**, which is connected to the spindle **236** via projections **242**. The spindle **236** includes a driver slot **244** in it through which a spring tang **246** formed at the first end **248** of the spring **226**. The second end of the spring **226** is shown at **250** and engages the tensioner arm **224**. Rotation of the spindle **236** therefore causes rotation of the first end **248** of the spring **226**. In a low tension situation, the tensioner **200** may engage the belt **14** with the arm **224** positioned as shown in FIG. **5***a*. Rotation of the first end **248** in a first direction **252** causes the biasing force of the spring **226** on the tensioner arm **224** to increase progressively, thereby increasing the tensioning force of the tensioner arm **224**, or more specifically the pulley **222**, on the belt **14**. Increasing the tensioning force causes rotation of the arm **224** in the clockwise direction in the views shown in FIG. **5***a*-**5***c*, until the tension in the belt **14** increases sufficiently that an equilibrium is reached between the tensioner arm **224** and the belt **14**. FIGS. **5***b* and **5***c* show the tensioner **200** when the tensioning force has been increased from the low tension setting in FIG. **5***a*, to midlevel tension setting (FIG. **5***b*), and to a high tension setting (FIG. **5***c*) respectively. It will be noted that the flights of the worm **232** are preferably configured to prevent the worm from being backdriven by the sector gear **234** so that when there is high tension in the belt **14**, the biasing member **326** cannot relieve itself by backdriving the worm **232**. If the rotation is in a second direction shown by arrow **254** in FIG. **4***a*, the tensioning force applied to the belt **14** is reduced progressively.

The tensioner **200** is provided with two sensors shown at **260** and **262** respectively. The sensor **260** is provided for measuring the speed of the pulley **222** and may be similar to the sensor **72** shown in FIG. **2***a*. The sensor **262** is provided for measuring the position of the tensioner arm **224**. The sensor **262** may be any suitable type of sensor. For example it may be an angular position sensor, which is stationary and which can detect changes in the angular position of a circular (or, more precisely, disk-shaped) magnet **264** which is connected for rotation with the tensioner arm **224** and is aligned with the hub axis Ah (FIG. **4***b*). The magnet **264** has a north pole that makes up 180 degrees of the magnet (i.e. a hemi-disk), and a south pole that makes up the other 180 degrees (i.e. the other hemi-disk). The position sensor **262** may be any suitable type of sensor that can detect the change in the position of the north and south poles of the magnet **264** as the arm **224** pivots about the hub axis Ah. An example of a suitable sensor is a model 2SA-10 Sentron sensor provided by Sentron AG, of Zug, Switzerland. A suitable position sensing system (made up of a sensor like sensor **262** and a circular magnet like magnet **264**) is shown and described in U.S. Pat. No. 7,188,021, which is incorporated herein by reference in its entirety. Instead of providing two sensors **260** and **262** in the tensioner **200**, it would be possible to omit one of the sensors **260** or **262**, or to provide the tensioner **200** with neither of the sensors **260** or **262**.

Another sensor (not shown) may be provided to determine the position of the first end **248** of the biasing member **226**.

The information from the sensors may be sent to the controller **34** which may be programmed to use the pulley speed information from sensor **260** to determine the speed of the belt **14**, which the controller **34** can use when determining if there is any belt slip at one or more of the accessory pulleys or crankshaft pulley engaged with the belt **14**. The information from sensor **262** may be used by the controller **34** to determine the precise position of the tensioner arm **24** which the controller **34** can use to determine the tensioning force being applied to the belt **14** and therefore the tension in the belt **14**. The controller **34** can use this information as feedback to assist it in controlling the actuator **222** in order to apply a selected amount of tension in the belt **14** using any of the algorithms described herein.

Reference is made to FIGS. **6** and **7***a*-**7***c*, which describes a tensioner **300** in accordance with another embodiment of the present invention. The tensioner **300** may have a hub **321**, a tensioner arm **324** that has a pulley **322**, a biasing member **326** that drives the arm **324** towards the free arm stop position, and an actuator **328** that drives a spindle **336** that drives one end of the biasing member **326** to control the biasing force, and therefore the tensioning force, and therefore the belt tension. All of these components may be similar to their counterparts, **221**, **222**, **224**, **226**, **228** and **236** shown in FIGS. **4***a*-**4***c*, except that the tensioner arm **324** has a projection **370** that extends downwards into a slot **372** on the spindle, shown at **336**. Referring to FIGS. **7***a*-**7***c*, FIG. **7***a* shows the tensioner **300** at a low tension setting. It will be noted that all of the tensioner arm **324**, except for the projection **370** has been omitted from FIGS. **7***a*-**7***c* so as to show the projection **370** and the slot **372** more clearly. As can be seen in FIG. **7***a*, at this setting, the projection **370** is roughly in the middle of the slot **372**, spaced from both ends, shown at **374** and **376** of the slot When the controller **34** determines that the belt tension should be raised, the motor shown at **330** drives the worm **332**, which drives the sector gear **334**, which drives the spindle **336**, which drives the first end **348** of the biasing member **326** thereby increasing the biasing force of the biasing member **326** on the tensioner arm **324**. This causes the tensioner arm **324** to rotate as it presses with more tensioning force into the belt **14**. FIG. **7***b* shows the tensioner arm **324** at a midlevel tension setting. It will be noted that in FIG. **7***b*, the projection remains spaced from both ends **374** and **376** of the slot **372**. As the controller **34** continues to drive the first end **348** of the biasing member **326**, the first end **348** of the biasing member **326** will rotate angularly towards the second end shown at **350**. If there is too much angular rotation of the first end **348** towards the second end **350**, it may be possible that the biasing member **326** could become damaged. To prevent this, as the first end **348** rotates towards the second end **350**, the first end **374** of the slot **372** on the spindle **336** rotates towards the projection **370**. If the first end **348** of the biasing member **326** rotates by a selected angular amount towards the second end **350**, the first end **374** of the slot **372** engages the projection **370**. At this point, if the actuator **328** continues to drive the rotation of the first end **348** of the biasing member **326**, the projection **370** (and therefore the tensioner arm **324**) will be driven to rotate by the first end **374** of the slot **372** so that the relative angle between the first and second ends **348** and **350** of the biasing member **326** cannot decrease any further. Because the relative angle between the first end **348** and second end **350** of the biasing member **326** no longer decreases with further rotation of the sector gear **334**, the biasing force applied by the biasing member **326** to the tensioner arm **324** no longer increases. However, because the tensioner arm **324** continues to be driven further and further into the belt **14** with further rotation of the sector gear **334** (by the motor **330**), the tension in the belt **14** continues to increase. FIG. **7***c* shows the tensioner arm **324** at a high tension setting where the projection **370** engages the first end **374** of the slot **372**.

It will be noted that the projection **370** could instead be on the spindle **336** and the slot **372** could instead be on the tensioner arm **324**. It will be further noted that there need not be a slot at all for engaging the projection **370**. For example, a first projection could be provided on the spindle **336** that extends radially outwards and upwards. A second projection could be provided on the tensioner arm **324** and could extend radially outwards, or optionally radially outwards and downwards. A first engagement surface on the first projection would engage a second engagement surface on the second projection if the relative angle between the first and second ends of the biasing member decreases below a selected angle, thereby preventing any further decrease in the relative angle.

The tensioner **300** may includes sensors similar to sensors **260** and **262** in the embodiment shown in FIGS. **4***a*-**4***c*.

Reference is made to FIGS. **8***a*, **8***b*, **9***a* and **9***b*, which shows a tensioner **400** in accordance with another embodiment of the present invention. The tensioner **400** may have a hub **421**, a tensioner arm **424** that has a pulley **422**, a biasing member **426** (FIG. **8***b*) that drives the arm **424** towards the free arm stop position, and an actuator **428** that may all be similar to the components **221**, **224**, **222**, **226** and **228** shown in FIG. **4***a*-**4***c*, except that the actuator **428** does not drive the first end shown at **448** of the biasing member **426**, and instead drives a spindle **436** that drives a bumper arm **475** that includes a second biasing member **476** and a cover **477**, into a projection **478** on the tensioner arm **424** to drive the tensioner arm **424** (more specifically the pulley **422** on the tensioner arm **424**) into the belt **14**, thereby controlling the tensioning force, and therefore the belt tension. FIG. **9***a* shows the tensioner in an unboosted state. This may be considered a low tension setting, and the first biasing member **426** may be selected to have a spring constant that is relatively low for this purpose and may be configured to exert a relatively low biasing force on the tensioner arm **424** for this purpose. In this state the bumper arm **475** is unengaged with the projection **478** on the tensioner arm **424** and so the tensioner **424** operates as a typical tensioner according to the response curve **102** shown in FIG. **1***c*. It will be noted that in this state, the bumper arm **475** is sufficiently out of the way that the tensioner arm **424** can pivot throughout a desired range of motion without engagement between it and the bumper arm **475**.

When it is desired to boost the tension in the belt **14**, the motor shown at **430** drives worm **432**, which drives sector gear **434**, which drives spindle **436** to bring the bumper arm **475** into engagement with the projection **478** on the tensioner arm **424** (shown in FIG. **9***b*), so as to urge the tensioner arm **424** into the belt **14** to increase the tension in the belt **14**. Once engagement between the bumper arm **475** and the tensioner arm **424** occurs, further rotation of the motor **430** results in a progressively greater amount of compression of the second biasing member **476**, which increases the amount of force it applies to the tensioner arm **424**. This in turn increases the tensioning force applied by the tensioner arm **424** on the belt **14** which in turn increases the belt tension. Because the motor **430** is only engaged with the tensioner arm **424** through the second biasing member **476**, the tensioner arm **424** can still pivot to accommodate dynamic fluctuations in belt tension even when the tension is being boosted, or more broadly, even when the tensioner arm **424** is engaged by the bumper arm **475**.

Referring to FIG. **9***b*, a moment arm M1 exists between the line of action through the pulley axis Ap of the pulley **422** and the pivot axis Ah of the tensioner arm **424**. A moment arm M2 exists between the line of action of the bumper arm **475** on the projection **478** and the pivot axis Ah. It is optionally possible to configure the tensioner **400** so that the moment arm M2 is greater than the moment arm M1 so as to facilitate driving the pulley **422** into the belt **14** against the force exerted by the belt **14** on the pulley **422**.

The tensioner **400** may include one or more sensors. A sensor shown at **460** may be similar to sensor **260** and is used for determining the speed of the pulley **422**. A sensor shown at **462** may be similar to sensor **262** and is used for determining the position of the tensioner arm **424**. A sensor shown at **465** is provided for determining the force applied by the second biasing member **476** on the tensioner arm **424**, which is used in addition to the information from the sensor **462** which provides tensioner arm position information and therefore information regarding the force applied on the arm **424** by the first biasing member **426**, so as to determine the tensioning force being applied to the belt **14**. This can be used as feedback for the controller **34** while driving the motor **430** to boost the belt tension, in order to determine at what position to stop the motor **430**. The sensor **465** may be, for example, a button load cell mounted to the cover **477**. Instead of the sensor **465**, the bumper arm **475** may contain a displacement measurement sensor **466**, which can be used to measure the length of the bumper arm **475**, thereby indicating the amount of compression there is in the second biasing member **476**. This can be used by the controller **34** to determine the force exerted by the second biasing member **476** on the projection **478**, which can be used to determine the overall tensioning force applied by the tensioner **400** on the belt **14** and thereby determine the belt tension. The displacement measurement sensor **466** may be configured to signal the controller only when in extended and retracted positions, or may be configured to signal to the controller **34** when it reaches any of three or more positions.

When it is desired to position the tensioner **400** in a low tension setting, the motor **430** may be rotated in the opposite direction as when boosting tension. When the controller **34** detects that the sensor **465** no longer senses any engagement between the bumper arm **475** and the projection **478**, the controller **34** may be programmed to rotate the motor **430** by a selected number of revolutions to bring the bumper arm **475** sufficiently out of the way to accommodate the pivoting of the tensioner arm **424** when operating at the low tension setting.

It will be noted that, in the embodiment shown in FIGS. **8***a*, **8***b*, **9***a* and **9***b*, the element that holds the first end of the biasing member **426** is fixedly mounted to the hub **421** so that the first end of the biasing member **426** remains stationary and is not rotated with the spindle **436**.

Reference is made to FIG. **10**, which shows a tensioner **500** in accordance with another embodiment of the present invention, which includes a hub **521**, a pulley **522**, a tensioner arm **524**, a biasing member **526** and an actuator **528**, which is controlled by controller **34**. The actuator **528** includes, among other things, a motor **530**, a worm **532**, a sector **534** that is connected for rotation with a spindle **536**. The tensioner **500** may be similar to the tensioner **400** except that in the tensioner **500**, the element that holds the first end of the biasing member shown at **526** is part of the spindle (shown at **536**). FIG. **11***a* shows the tensioner **500** at a low tension setting. In this state, the bumper arm shown at **575**, which may be similar to bumper arm **475**, is out of the way of the projection shown at **578** on the tensioner arm **524** so that the tensioner arm **524** can pivot throughout some range of motion as a result of engagement with the belt **14** without contacting the bumper arm **575**. FIG. **11***b* shows the tensioner **500** at a high tension setting. To boost the tension in the belt **14**, the bumper arm **575** is driven by the motor shown at **530** toward the projection **578**. This drives the first end **548** of the biasing member **526** however, which increases the torsion in the biasing member **526**, and therefore drives the tensioner arm **524** to rotate further into the belt **14**, increasing the belt tension. At some point, the spindle **536** is rotated sufficiently relative to the tensioner arm **524** that the bumper arm **575** engages the projection **578**. At that point, further driving of the spindle **536** drives the bumper arm **575** further into engagement with the projection **578** which increases the biasing force applied by the biasing member **526**, and which also increases the biasing force applied by the second biasing member shown at **576** which is part of the bumper arm **575**. This assists in preventing damage to the first biasing member **526** resulting from overrotation of the first end **548**, because the presence of the bumper arm **575** provides assistance so that a selected belt tension can be reached without all of the force having to be generated through the first biasing member **526**. The remote drive arrangement shown for the tensioner **500** may be applied to any of the tensioners shown and described herein where a motor is utilized and would benefit from being positioned away from the engine block.

The tensioner **500** may includes sensors similar to the sensors **460**, **462** and **465** shown in FIGS. **8***a* and **8***b* and a displacement measurement sensor similar to displacement measurement sensor **466**.

Reference is made to FIG. **12**, which shows a tensioner **600** in accordance with another embodiment of the present invention. In a situation where the temperature in the immediate environment of the motor is high, the operating efficiency of the motor decreases, sometimes significantly. This is due to several factors, including the fact that the resistance of the copper wire in the motor increases with temperature. Thus at 60 degrees Celsius or at 80 degrees Celsius, the wire has a higher resistance than it does at 25 degrees Celsius. As a result, the torque capability of the motor is reduced at high temperature. To compensate for this the motor may have to be upsized significantly in order to be assured of being able to handle a given torque requirement. To assist in keeping the cost of the motor shown at **630** low, the tensioner **600** may be similar to the tensioner **200** except that the tensioner **600** includes a remote drive arrangement in that the motor **630** is operatively connected to the worm **632** through a flexible shaft **680**. The flexible shaft **680** permits mounting the motor **630** away from the engine block, which means it may be possible to keep the motor **630** at a lower temperature than one that is mounted to or proximate to the engine block. The motor **40** may be positioned in a particularly cool part of the engine bay, such as near the grill or at some other cool air inlet. This would permit a less expensive motor to be used since it would not need to be oversized to compensate for a reduction in efficiency resulting from operating temperature.

Also, in any of the embodiments wherein a motor drives either the tang of the biasing member or drives a bumper arm, a locking mechanism (not shown) can be brought into provided to lock the spindle in a particular position. The locking mechanism may include a pawl or the like that engages an aperture or a detent or the like in the spindle. The spindle may include only a single aperture or detent, and is thus only held when it reaches a certain position, or it may have a plurality of plurality of apertures or detents about its circumference so that it can be held in a plurality of different positions. An actuator, such as a solenoid, would be provided to withdraw the pawl from the aperture/detent to permit the spindle to move to a different position or to return to a home position. Instead of this, the locking mechanism could include a cam that engages the tensioner arm, a wrap spring or any other suitable means.

If a gearbox is provided (as shown at **682**) to reduce the speed and increase the effective torque provided by the motor **630**, it is preferable that the gearbox be provided at the outlet end of the flexible shaft **680** (i.e. between the flexible shaft **680** and the worm shown at **632**), as opposed to providing the gearbox between the motor **630** and the flexible shaft **680**. As a result, the flexible shaft **680** is not relied upon to transmit high torque, which can result in its premature wear and/or windup in the flexible shaft **680**. The remote mounting of the motor **630** permits the motor **630** to be positioned in a particularly cool part of the engine bay, such as near the grill or at some other cool air inlet.

Reference is made to FIG. **13***a*, which shows a tensioner **700** in accordance with another embodiment of the present invention. The tensioner **700** includes a hub **721**, a tensioner arm **724** that is pivotable about a hub axis Ah, a pulley **722** mounted on the tensioner arm **724** for rotation about a pulley axis Ap, a biasing member **726** engaged between the hub **721** and the tensioner arm **724** to bias the tensioner arm **724** towards the free arm stop position, and a tensioner actuator **728**. The tensioner arm **724** shown in FIG. **13***a* includes a central portion **724***a* and an extendable portion **724***b* that is extendable from the central portion **724***a* by the actuator **728**. A motor **730** that is mounted on the central portion **724***a* and drives a lead screw **790**, which in turn causes linear movement of a traveler **792** mounted at one end of the tensioner arm **724**. This linear movement causes extension or retraction of the tensioner arm **724** depending on the direction of rotation of the motor **730**. Referring to FIGS. **13***c* and **13***d*, changing the length of the tensioner arm **724** (shown at L) changes the moment arm between the pulley **722** and the hub axis Ah, and also changes the hubload angle. Changing these properties changes the tensioning force applied by the pulley **722** on the belt **14**, which depends at least in part on the moment arm M2 of the pulley **722** as compared to the moment arm M1 of the biasing member **726**. Thus, when the moment arm of the biasing member **726** is constant as shown in FIG. **13***a*, reducing the length L of the tensioner arm **724** increases the tension in the belt **14** because it increases the force of the pulley **722** acting on the belt **14**. Similarly, extension of the tensioner arm **724** decreases the moment arm of the tensioner arm **724** on the belt **14**, which decreases the tension in the belt **14**. The length of the tensioner arm **724** may be determined using any suitable type of sensor, such as a Hall effect sensor that counts revolutions of the leadscrew **790**. In order to stabilize the arm **724** during use, the extendable portion **724***b* may be generally U-shaped (albeit with a very shallow U in the embodiment shown in FIG. **13***b*). To further stabilize the arm **724**, a clamping mechanism (not shown) may be provided which removes any play that exists between the extendable portion **724***b* and the central portion **724***a*. It will be noted that any of the tensioners shown and described may include a damping member as is known in the art to dampen oscillations of the tensioner arm. The damping force from the damping member is preferably proportional to the torque applied.

Reference is made to FIGS. **14***a* and **14***b*, which shows a tensioner **800** in accordance with another embodiment of the present invention. The tensioner **800** may be similar to the tensioner **200** except that the tensioner **800** includes an actuator **828** that includes a motor **830** that turns a lead screw **890** which has a traveler **892** thereon. The traveler **892** engages projections **894** on the spindle, shown at **836**. The spindle **836** engages the first end **848** of the biasing member **826** so as to control the biasing force of the biasing member **826** on the tensioner arm shown at **824**. The tensioner **800** further includes a hub **821** that mounts to the engine. A pulley **822** is mounted for rotation on the tensioner arm **824**.

Use of Hydraulic Actuator

Referring to FIGS. **15-43**, a tensioner **910** is shown for an endless drive member **911** along with several components engaged with the belt **911**, including the MGU **16** (or alternatively an alternator **16**) along with its pulley **54**, the a/c compressor **18** along with its pulley **60**, the crankshaft pulley **12** and an additional driven pulley shown at **915**, which could be from an accessory such as the water pump **55** (FIG. **3***a*). The pulley **915** includes a hydraulic actuator **913** which includes a cylinder **912**. The cylinder **912** includes a first housing **914** and a first piston **916**. The cylinder **912** at least partially defines a fluid chamber **918**. The first piston **916** defines a first end of the fluid chamber **918**. In the embodiment shown, the hydraulic actuator **913** further includes a second housing **920** (which may be referred to as a reservoir) is provided that is connected to the first housing **914** via a fluid passageway **922** (FIG. **18**) having a selected resistance to fluid flow. The second housing **920** defines part of the fluid chamber **918**. A second piston **924** is movable in the second housing **920** and defines a second end of the fluid chamber **918**. The fluid in the fluid chamber **918** (during use) is preferably a substantially incompressible fluid such as hydraulic oil. A first piston biasing member **926** is positioned to bias the first piston **916** towards the extended position (shown in several figures including, for example, FIG. **18**). A second piston biasing member **928** such as a spring is optionally provided, to assist in urging the second piston **924** into engagement with the fluid in the fluid chamber **918**, even though this could be accomplished with a gas in the second housing **920** instead of the spring. A second piston position control device **930** is provided to control the position of the second piston **924**. The control device **930** may include a threaded rod **932** that engages a threaded portion **934** at the end of the second housing **920**. The threaded rod **932** may be rotated in one direction to drive it in towards the second piston **924** or in another direction to drive it away from the second piston **924**. The threaded rod **932** may be used to set a limit position for the second piston **924**. This limit position may be chosen so that the second piston **924** can be pushed by the fluid in the fluid chamber **918** by some selected amount. Alternatively, the threaded rod **932** could be brought right up into abutment with the second piston **924** so as to prevent the fluid from pushing the second piston **924** at all. Alternatively, the threaded rod **932** could be rotated to drive the second piston **924** forward by some selected amount, thereby forcing the first piston **916** towards the extended position.

The first piston **916** is pivotally mounted at an external end to a base structure shown at **917***a* via a first cylinder pivot stud **919**, about a cylinder pivot axis ACYL. The external end of the housing **914** is pivotally connected to a lever arm **936**, via a second cylinder pivot stud **921**, about a lever arm engagement axis ALAE. The first and second pivot studs **919** and **921** are simply elements about which the ends of the housing **914** and piston **916** can pivot. They may alternatively be referred to as pivot posts **919** and **921**.

The lever arm **936** is pivotally connected via a pivot stud **923** to a base structure **917***b* about a lever arm pivot axis ALAP. The base structure **917***a* and the base structure **917***b* may both be part of the same component, such as the engine block. Alternatively they may be portions of different components. A pulley **938** is rotatably mounted to the lever arm **936**. The pulley is engaged with the endless drive member **911** to tension the endless drive member **911**. In an alternative embodiment, it is possible for the pulley **938** to be directly mounted to the external end of the housing **914** and to omit the lever arm **936**. In such an embodiment, the movement of the housing **914** would be constrained in some way, such as by guides that force it to travel linearly.

The threaded rod **932** may be driven to rotate by a motor shown at **940** optionally via a flexible shaft shown at **942**. The motor **940** may be fixedly mounted (e.g. to a base structure that is spaced from the engine block) and the flexible shaft **942** may permit operative connection of the motor **940** to the threaded rod **932** even though the threaded rod **932** moves during operation of the tensioner **910**. By mounting the motor remotely from the engine block it may be possible to keep the motor **940** at a lower temperature than one that is mounted to or proximate to the engine block. This would permit a less expensive motor to be used. Alternatively as shown in FIG. **14**, the motor **940** may be mounted to the second housing **920**, in which case a shaft that is flexible is not necessary.

If a gearbox is provided to reduce the speed and increase the effective torque provided by the motor, it is preferable that the gearbox be provided at the outlet end of the flexible shaft (i.e. between the flexible shaft **942** and the threaded rod **932**), as opposed to providing the gearbox between the motor and the flexible shaft **942**. As a result, the flexible shaft is not relied upon to transmit high torque, which can result in its premature wear and/or windup in the flexible shaft.

Where the motor **940** is positioned remotely from the second housing **920**, the motor **940** may be positioned in a particularly cool part of the engine bay, such as near the grill or at some other cool air inlet.

The operation of the motor **940** may be controlled by any suitable control system. A generic control system is shown at **943** in FIG. **15**. The control system **943** may be made up of one or more individual components (e.g. one or more control units). The control system **943** may include the main ECU of the vehicle, or it may be separate from the main ECU of the vehicle. In an embodiment, the control system **943** may be a separate controller that communicates with the ECU of the vehicle via a wiring harness or via a CAN bus. A number of suitable types of relationship may exist between the ECU and any other controllers that together form the control system **943**. For example, the ECU may sometimes or may all the time be a master to the other controllers in the control system **943**.

The control system **943** may set the position of the threaded rod **932** using the motor **940** based on any suitable set of parameters. The control system **943** may, for example, drive the threaded rod **932** inwards to move the second piston **924** so as to move the first piston **916** to provide a selected high tension in the belt **911** in some situations where the control system **943** determines that the belt **911** is determined to be at risk of slippage or if slippage has been detected. An example of such a situation is upon startup of the vehicle, particularly on a cold day. Another example of such a situation is upon startup during a BAS (Belt Alternator Starter) belt starting sequence, where high belt tension is required only during the initial motor/alternator belt starting sequence, to spin the engine crankshaft by the belt. Another example of such a situation is during moments where there is high engine acceleration or deceleration.

The control system **943** may also drive the threaded rod **932** outwards to a position where it permits the second piston **924** to travel freely in the second housing **920** where, for example, a lower tension is acceptable for the belt **911** without risk of belt slippage. In some situations, the control system **943** may drive the belt inwards so as to simply abut the second piston **924** so as to prevent the second piston from permitting compression of the cylinder **912**. This can be used during periods of belt flutter or belt resonance, during periods of high belt drive rotation torsional acceleration (engine torsionals), or for example, during situations where a system disturbance (e.g. belt flutter) is anticipated based on inputs from one or more sensors, in order to prevent tension loss/reduction due to the tensioner being forced back out of the belt during such periods of instability.

The control of the motor **940** by the control system **943** may be open-loop or may be closed loop whereby the control system **943** receives inputs from one or more sensors that indicate whether the position of the threaded rod **932** is as intended. Additionally the control system **943** may receive inputs from one or more other sensors which it uses to determine where to position the threaded rod **932**. Such sensors may include, for example, temperature sensor, a rain sensor, a sensor related to belt slip, and the like. Suitable algorithms for the control system **943** are described in copending application 61/486,189, the contents of which are incorporated herein by reference.

The L-shaped configuration between the cylinder **912** and the second housing **920** facilitates rapid tuning using take apart components which can be switched out as required. However, an in-line configuration may alternatively be provided. Furthermore, a monotube configuration may be provided in which the entire fluid chamber and both the first and second pistons are contained in a single cylinder housing. In a monotube configuration, the connector at the external end of the housing could be shifted to the side so as to make room for the threaded rod to enter into the housing through the end of the housing.

In an alternative embodiment, the piston **916** and housing **914** could be reversed, whereby the piston **916** is connected to the lever arm **936** and the housing **914** is pivotally connected to the engine block.

In one aspect, the novel concept here is to block the return of the second piston to induce hydraulic lockout (piston lockout) thereby preventing, on demand, any retraction of the first piston **916** (i.e. compression of the cylinder **912**) in response to a specific FEAD belt drive system requirement.

In another aspect, the novel concept here is to drive the small reservoir position in power mode, to extend (or retract) the strut to amplify the force by driving the first piston which may be larger than the second piston.

Different travel rates and load outputs can be achieved by manipulating the piston diameter ratios between the diameter of the first piston **916** and the diameter of the second piston **924**.

In some embodiments the connection between the first housing **914** and the second housing **920** could be separated by a flexible hose—a stiff flex steel braided hose, for example, would probably be employed in such a case so as to minimize unwanted expansion of the hose under pressure, resulting in unwanted diametral elastic growth of the hose/tubing, which would ultimately result in adding an unwanted lag, or delayed response, to the final spring rate. Unwanted elasticity on the high pressure oil side is preferably eliminated in order to prevent force response lags, hence the use of non-elastic hoses where practical.

In the exemplary embodiment presented in the illustrations, the majority of damping comes from the seals and damping rings installed within the first piston **916**, as well as whatever damping comes from the flow of fluid.

Extra damping can be added to the tensioner by introducing such devices as a small orifice restriction and a blow off ball valve in the oil flow between the two housings, to induce restrictive orifice damping and steady blow off damping.

In HYDRAULIC LOCKOUT MODE, the rod **932** merely stops the backward motion of the floating reservoir piston, which ultimately hydraulically locks the larger piston **916** and prevents further insertion of the piston rod into the cylinder housing **914**, effectively locking the tensioner arm **936**.

In POWERED DRIVE MODE, the rod **932** is used to push the smaller floating piston **924**, in order to force the larger tensioner cylinder piston **916** to move in response to the flow of oil from the reservoir **20**. The technique, for example, may be used to push the pulley **938** harder into the belt under conditions where belt slip would otherwise be imminent, such as during a BAS start (in hybrid vehicles), or during wet or extremely cold conditions.

The rod **932** used to lock out or drive the reservoir piston **924** can be driven via a fine lead screw arrangement, as depicted in the figures, or it could be driven linearly (as opposed to the rotational actuation required by a lead screw arrangement) by a powerful linear solenoid—any actuator device which is capable of blocking movement of the smaller reservoir piston **924** or of driving the reservoir piston **924** (in powered drive mode described below) could be employed. The solenoid may actuate the rod **932** linearly via a flexible cable (e.g. a Bowden cable). This would permit the solenoid to be mounted remotely in a cooler spot in the engine bay, (e.g. near the grill) in similar manner to the remote mounting of the motor **940**, described above. An example of a suitable solenoid with a flexible cable arrangement that may be used in some embodiments is provided by Trombetta, which is owned by Fulham & Company, and is located at Menomonee Falls, Wisconsin, USA.

It will be understood that, under typical conditions where temperature is not an issue, it is preferred to mount the motor **940** or solenoid in substantially direct engagement with the rod **932** (as opposed to a remote mounting with a flexible shaft or push/pull cable between them) so as to reduce the number of components between the motor **940** or solenoid and the rod **932**, so as to increase the torque transfer efficiency between the motor **940** or solenoid and rod **932**. However, in a situation where the temperature in the immediate environment of the load will be high and the motor is in that environment, the operating efficiency of the motor decreases, sometimes significantly. This is due to several factors, including the fact that the resistance of the copper wire in the motor increases with temperature. Thus at 60 degrees Celsius or at 80 degrees Celsius, the wire has a higher resistance than it does at 25 degrees Celsius. As a result, the torque capability of the motor is reduced at high temperature. To compensate for this the motor may have to be upsized significantly in order to be assured of being able to handle a given torque requirement.

The threaded rod **932** is in a hot environment due to its proximity to the engine. By mounting the actuator (e.g. the motor **940** or the solenoid) remotely from the rod **932**, the actuator can be placed in a cooler environment where its operating efficiency is not degraded, or not degraded as much as it would be in the hotter environment. For example, the actuator may be placed near the grille of the vehicle where it is exposed to a strong airflow for cooling purposes.

Also a remote mounting of the actuator can be advantageous if there are space and size limitations proximate to where the rest of the tensioner **910** is mounted.

Instead of using a solenoid, a vacuum actuator can be used in some embodiments to drive the rod **932** linearly. The vacuum actuator may draw power from the vacuum drawn from the air induction system. Vacuum drawn from the air induction system has been used in the past for other purposed such as to drive turbo waste gate motors and manifold induction duct actuator motors, for example.

In some embodiments a pneumatic actuator may be used to drive the rod **932** if a compressed air supply is available onboard the vehicle. Alternatively, a hydraulic actuator could be used, drawing power from a source of hydraulic fluid, such as the power steering system in vehicles that use a hydraulic power steering system, or, for example from the engine oil system. A compressed air supply, a hydraulic power supply, or a vacuum source are sometimes available on certain vehicles such as trucks and SUVs.

A vacuum actuator, a pneumatic actuator, or a hydraulic actuator may be switched via a relatively inexpensive solenoid powered valve, and could be controlled electronically, via either an analog or digital signal, from the control system **943**.

An example of a suitable actuator may be a door lock actuator, similar to (but perhaps scaled up in power and resistance to high temperature) those described in US Patent Nos. U.S. Pat. Nos. 6,067,826, 5,983,739, 5,634,676 the contents of all of which are incorporated herein by reference. Such an actuator could be used successfully in some embodiments by incorporating a gearbox with worm drive and a high gear ratio. Backdriving of such an arrangement can be prevented by the worm drive (in embodiments wherein it is provided) and/or by providing some other structure such as one or more detent lock features, with a spring loaded lock and load feature as described in U.S. Pat. No. 5,983,739, the contents of which are hereby incorporated by reference.

While a push-pull cable has been described as being usable in certain embodiments, other arrangements may be used, in addition to or instead of a push-pull cable. For example a linkage may be used such as the linkage shown in U.S. Pat. No. 5,634,676 the contents of which are hereby incorporated by reference, optionally with a push-pull cable. Using some linkages linear motion could be converted to rotary motion, or vice-versa. Such linkages may be used to alter the mechanical advantage by increasing force by reducing displacement, or by decreasing force by increasing displacement, depending on the embodiment.

The first piston biasing member **926** may be a coil spring, as shown in the figures, or it may be some other type of spring such as a closed cell foam (CCF) spring as shown in FIG. **27**. It could alternatively incorporate both a coil spring and a closed cell foam spring. An example of such a spring is supplied by BASF. An advantage to CCF springs is that they can collapse to only 20% of their original height (vs 40% for some steel coil springs). Another advantage to CCF springs is that it is easy to manufacture them with a desired constant spring rate or a spring rate that varies with the amount of compression of the CCF spring. This may be achieved by co-molding portions (e.g. layers) of the CCF spring, each having different properties. Properties that may be varied include density of the CCF, the cell size, the outer diameter and inner diameter of the CCF spring (in embodiments wherein they are hollow-cylindrical. Additionally you can easily tune their design to provide a selected amount of energy dissipation. The shorter collapsed length of the CCF spring could be used to provide a larger linear travel of the cylinder **912** for a given overall length of the cylinder **912**. As another alternative, the first piston biasing member may include some other type of biasing member such as, for example, one or more Belleville washers, one or more wave washers, gas pressure, or a combination of two or more of these. All of these alternatives may also be used as the second piston biasing member **928** instead of or in addition to a coil spring.

In an example, the CCF spring may be used just as an end-of-travel jounce stop, to impart an elastically damped, high spring rate at the end of travel of a typical coil spring design. In another example, the CCF spring may be molded around metal coil springs or washer springs to impart new spring and new jounce stop properties to the overall spring assembly.

In an alternative embodiment shown in FIG. **25**, the second piston biasing member **928** may be positioned between the second piston **924** and a limit member **944** that is in the second housing **920**. The threaded rod **932** engages the limit member **944**. This structure is particularly advantageous when using the threaded rod **932** to set a limit for the amount of retraction that is possible for the first piston **916** in the first housing **914**. With this structure, as the threaded rod **932** is advanced into the second housing **920**, it advances the limit member **944** towards the second piston **924**. This in turn causes the second piston biasing member **928** to compress, increasing its resistance to further compression. As a result, when the second piston **924** is moved to abut the limit member **944** because of an increase in tension in the belt **911**, the increased resistance offered by the biasing member **928** helps to reduce the abruptness of the engagement between the limit member **944** and the second piston **924**.

Reference is made to FIG. **26**, which shows another embodiment of the present invention. In this embodiment, the tensioner includes a hub **946** that is mountable to a base structure such as the engine block (not shown). A tensioner arm **948** is pivotable about the hub **946**. The pulley **938** is positioned at the end of the arm **948**. A tensioning spring (not shown) and a damping element (not shown) are positioned about the hub **946**, as they are in a typical tensioner. The cylinder **912** is mounted in such a way that one end (in this case the external end of the housing **914**) is pivotally mounted to a base structure, and the other end (in this case the external end of the piston **916**) is pivotally mounted to the tensioner arm **948**. The second housing **920** is provided, with the second piston **924** therein. In this embodiment, the threaded rod **932** is engageable with the second piston **924** only through the limit member **944** and the second biasing member **928**, however it is alternatively possible to omit the limit member **944** and to provide an arrangement similar to that shown in FIG. **24**, wherein the threaded rod **932** directly engageable with the second piston **924**. The tensioner shown in FIG. **26** may act substantially like a typical tensioner. However, the additional structure including the cylinder **912** and related components, permits the tensioner arm **948** to be locked hydraulically as described above (ie. by engagement of the threaded rod **932** or limit member **944** so as to prevent complete compression of the cylinder **912**), and to be driven to a different (higher tension) position via the threaded rod **932** and a suitable actuator (eg. motor **940** and flexible shaft **942**).

Reference is made to FIGS. **29***a* and **29***b* which show alternative structures for locking the tensioner **910** and for boosting the tension in the tensioner **910**. A needle valve shown at **952** may be provided for controlling the flow of fluid between the first chamber portion shown at **918***a*and the second chamber portion shown at **918***b*. The needle valve **952** includes a flow control element **954** that is positionable in at least an open position wherein flow through the passageway **922** is permitted and a closed position (FIG. **29***b*) wherein flow through the passageway **922** is prevented. The flow control element **954** may be positionable in only those two positions (by means, for example, of a two-position solenoid) or alternatively it may be positionable in three or more positions. In some embodiments it may be infinitely adjustable in position via proportional control. When the flow control element **954** is in the closed position, the tensioner **910** is locked hydraulically in position, in similar manner to the embodiment shown in FIGS. **15-28** in which the threaded rod **932** is adjusted to abut the second piston **924**. When the flow control element **954** is in the open position it does not prevent the cylinder **912** from extending and retracting. When the flow control element is positionable in one or more partially open positions, an example of which is shown in FIG. **29***a*, it can be used as an adjustable orifice to control the rate of flow of fluid between the chamber portions **918***a* and **918***b*, thereby controlling the rate of extension or retraction that is available to the cylinder **912** and acting as a damping member. While the threaded rod **932** is shown in FIGS. **29***a* and **29***b* it is not needed and the second housing **920** could simply have a closed end instead.

Also shown in FIGS. **29***a* and **29***b* is an alternative tension boost mechanism shown at **955**. The tension boost mechanism includes a fluid reservoir **956** and a pressure source **957**, such as an electric pump. The pressure source **957** connects to the chamber portion **918***b* (or alternatively to somewhere else in chamber **918**), via conduit **958**. When it is desired to boost the tension, the pump **957** operates to pump fluid into the chamber **918**, forcing the second piston **914** backwards until the second biasing member **928** can no longer compress, and forcing the cylinder **912** to extend to drive the pulley **938** into the belt **911**. When a desired tension is reached in the belt a valve (not shown) in conduit **958** can be closed which would still permit the tensioner **910** to extend and retract, or alternatively, the locking valve **952** could be closed, however this would lock the tensioner **910** in position.

Reference is made to FIG. **30**, which shows the controller **34**. As described above the controller receives input **960** that may include any one or more of the following:

Engine ECU Parameters

Time information, which provides daily driver information such as time of vehicle use, days on/days off and the like;

Date information, which provides seasonal time of year approximations, and which may be available from SAT radio/GM OnStar™/Ford Sync™/ECU with battery backup;

Engine information, including RPM (based on crankshaft pulley speed)/engine on/engine start successful

Transmission information including transmission gear position & shift status which provides rate of acceleration/deceleration information for belt slip prediction/transmission downshift & upshift information,

Cruise Control information: prolonged steady state speed would imply that use of lower belt tension is permissible/no rapid engine RPM transitions

Vehicle ECU Parameters

Windshield wiper status—Via CAN bus

Windshield rain sensor—Via CAN bus

Traction control system wheel slip status (acceleration)—wheel slippage indicates wet or slushy road conditions—predicts belt contamination/belt slip probability

ABS system wheel slip status (braking)—wheel slippage indicates wet or slushy road conditions - predicts belt contamination/belt slip danger probability

Key fob Sensor in a simple embodiment it can be used to sense the approach of any driver and can adjust belt tension prior to initial cold engine start. In a more advanced embodiment it can sense approach of driver **1**/driver **2**—and can predicts driver driving style

Ignition Status: For a hybrid vehicle stop/start applications—if brakes are applied and if wheel speed =0 and engine RPM =0 would indicate to increase belt tension

Wheel Speed—Hybrid stop/start applications—if brakes are applied AND if wheel speed =0 AND if engine RPM =0 this is an indication to increase belt tension

Brakes—Hybrid stop/start applications—if brakes are applied AND if wheel speed =0 AND engine RPM =0 then this is an indication to increase belt tension

Engine RPM—Hybrid stop/start applications—if brakes are applied AND if wheel speed =0 AND if engine RPM =0 then this is an indication increase belt tension

Headlight Status—If the high beams are on this may indicate fog or some other wet condition in which it would be beneficial to increase belt tension

Throttle position sensor, and the Brake position sensor: this includes the actual positions of the accelerator pedal and brake pedal, and the rate of change in the positions of the accelerator pedal and the brake pedal: these may be used to indicate whether the vehicle is coming to a stop, is leaving a stopped condition, or is in a panic stop, or is in a panic acceleration

Driver selectable settings, such as the driving mode (LUXURY, SPORT, ECO, NORMAL—used to control shift map for the transmission and in some cases the suspension settings). Seat settings, mirror settings and the like may also be used to indicate to the vehicle which driver is in it, which can be used to indicate whether or not high tension in the belt is likely to be needed.

Fead Component Information

Battery voltage and battery outgoing current

Electric Fan on/off status—indicates that the alternator may need to be started to maintain the battery charge

Alternator regulator status (charge status : on/off)

Alternator speed via rotor rotation output

Alternator temperature

Alternator voltage

Alternator charge current

Hydraulic power steering pressure switch: this indicates power steering status—on/off, if traveling on a highway no turns are anticipated and so the hydraulic power steering usage is expected to be low

Electric power steering motor status: indicates power steering status—on/off, if traveling on a highway no turns are anticipated and so the electric power steering usage is expected to be low

Air conditioning compressor clutch state : NC compressor shaft on/A/C compressor shaft off

Waterpump SWP clutch state : waterpump impeller on/waterpump impeller off

Idler pulley speed (for belt slip calculation where tensioner pulley speed sensor is not viable)

Tensioner pulley speed (for belt slip calculation where tensioner pulley speed is provided)

Tensioner arm angle position (measures tensioner arm rotation angle using the tensioner arm position sensor (e.g. shown at **462**)

Bumper arm information: This information could include: extended/retracted if using a two position sensor, or could include multiple positions between extended and retracted positions to provide more precise information regarding the force applied to the tensioner arm by the bumper arm. Optionally a continuous displacement sensor can be provided to indicate the amount of compression in the second biasing member more accurately. A load cell sensor could be provided which would provide direct information relating to the amount of force being applied by the bumper arm to the tensioner arm.

Spindle position sensor—measures rotation of spindle—which provides spring tang wind up angle in embodiments where the first end of the biasing member is moved by the actuator.

Dedicated Sensor Inputs

Temperature sensor for under hood (engine bay) temperature, close to FEAD belt drive

Humidity sensor for under hood (engine bay) humidity, close to FEAD belt drive

Temperature sensor—absolute outside ambient outdoor temperature

Humidity sensor—absolute outside ambient out door humidity

Dedicated Sensor and Calculation Procedures and Inputs

Pulley torsional vibration measurement can be as described in PCT publication WO2006045181 the contents of which are incorporated herein by reference.

Belt elongation and belt stretch measurement can be as described in PCT publication WO2007143830 the contents of which are incorporated herein by reference.

Belt flutter/belt twist may be detected as a vibration or as an underhood noise by acoustic microphones, vibration sensors, or perhaps, by simple "touch" proximity sensors.

Input **960** may also include any other input described herein and may include other inputs also not described herein. The controller **34** uses these inputs to determine whether or not the change the tension in the tensioner. The controller **34** controls the motor **962** accordingly which may be the motor in any of the embodiments described herein.

Use of Load/Pressure Sensors

Reference is made to FIGS. **31***a*-**43**, which illustrate embodiments with means for the determination of the tension in the belt **911**. In the tensioner shown in FIG. **31***a*, for example, a pressure sensor **970** may be mounted to sense the fluid pressure in the fluid chamber **918** and to send signals to the controller **943** that indicate the sensed fluid pressure. The controller **943** can determine the tension in the belt **911** using this fluid pressure combined with other data indicative of the geometric relationship between the cylinder **912**, the lever arm **936** and the hub load vector, shown at HLV. Examples of data that would be indicative of the aforementioned geometric relationship include the length of the cylinder **912**, or the angular position of the lever arm **936**. Even without the position data, however, the controller **943** could make a rough estimate of the belt tension by assuming that the cylinder **912** and the lever arm **936** are in a particular position, such as about halfway between the load stop and free arm positions.

The pressure sensor **970** may send signals to the controller **943** by either a hardwired connection, as shown in FIG. **31***a*, or via a wireless connection as shown in FIG. **31***b*. A wireless connection may use any suitable technology as, for example Bluetooth or Zigbee technologies.

The pressure sensor **970** may be mounted to the second housing **920**, as shown in FIG. **31***a*. Alternatively, the pressure sensor **970** may be mounted to something else, such as the first housing **914**. The pressure sensor **970** may be mounted so that it extends out from the second housing **920** (or from the first housing **914**). Alternatively, the pressure sensor **970** may be mounted within the fluid chamber **918** (e.g. within the second housing **920** or within the first housing **914**). While such an embodiment could be hardwired, it could alternatively be wireless, whereby it could be powered by way of a self-contained battery and could be programmed to go into a sleep mode when not in use so as to conserve energy so as to prolong the life of the battery, in similar fashion to tire pressure sensors installed on the wheels of some vehicles currently. The battery could have technology for harvesting energy from vibration or other sources in order to recharge itself. The use of a wireless transmitter from the pressure sensor **970** is preferable to a hardwired connection from the point of view of cost since the wired connection includes such costs as the electrical connectors, wiring harnesses and clips for them, and labour to install the wiring harnesses and clips.

The pressure sensor **970** may use any suitable technology for determining the pressure in the fluid chamber **918**. For example, the pressure sensor **970** may incorporate a strain gauge, or piezoelectric technology.

In the embodiment shown, the second housing **920** is mounted substantially parallel to the first housing **914**. This may be advantageous from a packaging perspective by being easier to fit into the sometimes tight space available about the engine in the engine bay of a vehicle. It will be noted, however, that the second housing **920** could be oriented in any other suitable orientation, such as the orientation shown in FIG. **15** wherein it is generally perpendicular to the first housing **914**.

Also, in the embodiment shown, the motor **940** used to drive the threaded rod **932** shown directly mounted to the second housing **920**, in similar fashion to the embodiment shown in FIG. **28**. It is alternatively possible for the motor **940** to be mounted elsewhere, such as remotely from the second housing **920** in similar fashion to the embodiment shown in FIG. **15**. An electrical connector **945** is shown extending from the back of the motor **940** for connection to a power source within the vehicle. In a preferred embodiment, the electric connector **945** is connected to the controller **943** such that the controller **943** controls the operation of the motor **940**.

The motor **940** shown in FIG. **31***a* includes an associated gearbox **941**. This gearbox **941** may, for simplicity's sake, be considered to be part of the motor **940**.

Referring to FIG. **32**, a load cell **972** may be used to detect the force exerted by the cylinder **912** on the lever arm **936**, which may be used along with other data by the controller **943** to determine the tension in the belt **911**, the other data being similar to that described above (i.e. data that is indicative of the geometric relationship between the cylinder **912**, the lever arm **936** and the hub load vector HLV), or which may be used without other data to estimate the belt tension.

In the embodiment shown in FIG. **32**, the load cell **972** is placed on the first piston and is a compression load cell. The load cell **972** may have any suitable configuration for sensing the force exerted through the piston **916** and therefore the force exerted by the cylinder **912** on the level arm. For example, the load cell **972** may be a canister load cell, an S- or Z-beam load cell, a bending beam load cell or a shear beam load cell.

The load cell **972** in this example is a wired load cell that is connected via electrical connector **973** to the controller **943**. The load cell **972** may alternatively be wireless and may incorporate a battery and a wireless transmitter for transmitting signals wirelessly to a receiver on the controller **943**.

In the embodiment shown in FIG. **33**, the load cell **972** is positioned on the first housing **914** instead of being positioned on the first piston **916**.

Referring to FIG. **34**, a hub load sensor **974** may be provided in any idler pulley that is driven by the belt **911**, such as, for example, the tensioner pulley **938** to determine the hub load incurred by that pulley. The hub load sensor **974** may have any suitable structure. For example, it may incorporate a compression-type strain gauge that acts between an inner race of a pulley bearing and a hub, as described in U.S. Pat. No. 6,484,593. The hub load sensor **974** may be used to detect the force of the belt **911** on the pulley **938** and so it constitutes a relatively direct way of determining the tension in the belt **911**. It will be understood that the belt tension can be determined based on the sensed hub load and based on other data indicative of the geometric relationship between the belt spans **911** a and **911** b on either side of the pulley **938** and the direction of the sensed hub load. The belt tension could altematively be estimated using only the hub load, without other data indicative of the geometric relationship between the belt spans **911***a* and **911***b*.

As shown in FIG. **34**, the hub load sensor **974** may be connected to the controller **943** via a hardwired connection. It is alternatively possible, however for the hub load sensor **974** to be powered by a battery and to have a wireless transmitter so as to transmit hub load information wirelessly to the controller **943**. The hub load sensor **974** may employ a strain gauge, as noted above, or piezoelectric technology, or any other suitable technology.

Referring to FIG. **35**, another way of determining the force of the belt **911** on the pulley **938** is by means of a bending load sensor **976** provided on a hub **978** of the pulley **938**, which determines the bending load applied by the belt **911** on the hub **978** through the pulley **938**. The bending load sensor **976** may be any suitable type of sensor, such as a bending beam load cell. The controller **943** can use the bending load sensed by the bending load sensor **976** either alone, or in combination with data indicative of the geometric relationship between the belt spans **911** *a* and **911** *b* on either side of the pulley **938** and the direction of the sensed bending load, to determine the belt tension. A suitable bending beam load cell may be the model LBB200 or LBB300 provided by Futek Advanced Sensor Technology, Inc. of Irvine, California, USA.

In similar fashion to the embodiments described above, the bending load sensor **938** may be connected to the controller **943** via a hardwired connection, as shown, or may transmit bending load information to the controller **943** wirelessly.

Referring to FIG. **36**, another way of determining the belt tension is to use a bending load sensor **980** on either (or both) of the cylinder pivot studs **919** or **921**, which senses the force exerted by the cylinder **912** on either the base structure **917***a* or on the lever arm **936** (it is the same force in both cases). In the embodiment shown, the bending load sensor **980** is provided on the stud **921**. The controller **943** can determine the tension in the belt **911** using the load sensed by the bending load sensor **980** either alone, or combined with other data indicative of the geometric relationship between the cylinder **912**, the lever arm **936** and the hub load vector, shown at HLV, in similar fashion to the belt tension determination made using the fluid pressure in the cylinder **912**. The bending load sensor **980** may be similar to the bending load sensor **976** and may be a bending beam load cell.

Another possible location for a bending beam load cell aside from the locations described above would be on the stud shown at **991** that is used to mount the lever arm **936** to the base structure **917***b*.

In embodiments wherein a bending beam load cell is used, or wherein a pulley hub load sensor is used, it will be noted that, due to movement of the various components of the tensioner during use, the orientation of the sensor may not be aligned always with the direction of the load acting on it. The controller **943** may attempt to compensate for this in some way so as to obtain a more accurate determination of the load itself. For example, it may compensate for this by obtaining data from one or more of the position sensors described above. Alternatively it may compensate for it by estimating the position of the components based on some other data, such as the force itself, or accelerometer data from an accelerometer or based on some other information. Alternatively, the controller **943** may simply use the load data from the load sensor without compensating for it, on the assumption that it provides sufficient accuracy in some embodiments.

In embodiments wherein a hub load sensor or a bending beam load cell is used, it may be used on any pulley (preferably an idler pulley) in the accessory drive. However, providing one of these devices on the tensioner pulley **938** or on the cylinder **912** permits it to be oriented relative to the tensioner arm **936** in a selected way so that it is in a selected orientation as soon as the tensioner is installed on the engine. Optionally, the hydraulic actuator **913**, the biasing member **926**, the tensioner arm **936** and the pulley **938**, could be provided on a single support bracket (not shown) that is itself mountable in a predetermined orientation to the engine. This would permit a bending beam load cell mounted in the stud **919** to be already oriented in a selected orientation when the tensioner is installed on the engine.

In embodiments wherein load-related sensors are provided (e.g. the pressure sensor, the load cells, hub-load sensors, strain gauges and the like in the embodiments shown in FIGS. **31***a*-**36**), the sensors can be used to provide feedback to the controller **943** so that closed loop control can be carried out when the controller **943** is driving the motor **940** in order to achieve a selected belt tension. Any closed loop control scheme could be used, such as PID control, fuzzy logic, etc. Alternatively, the controller **943** may control the motor **940** using open loop control. In such a case it would simply drive the motor a selected number of turns according to a look up table stored in memory, to bring the second piston **924** to a selected position.

Use of Accelerometer

Referring to FIG. **37**, an accelerometer shown at **982** may be provided on a moving element in the tensioner. The accelerometer **982** may be similar to those provided in some video game controllers and smartphones today and is capable of detecting movement of an object. The accelerometer **982** may be positioned on the lever arm **936** (shown in this embodiment to have a different shape than the lever arm **936** in other embodiments herein, in order to accommodate the accelerometer **982**). The accelerometer **982** could alternatively be positioned on some other member, such as on one of the first or second housings **914** or **920**, or possibly even on the first piston **916** (so as to detect the angular movement of the piston **916** about the pivot axis ACYL). The accelerometer **982** provides acceleration data to the controller **943**, which can be used to detect both the amplitude and the frequency of the changes in acceleration of the lever arm **936** (or of whatever part that it is mounted to). Rapid and/or large changes in acceleration may indicate instability (e.g. resonance) in the tensioner, and may thus trigger the controller **943** to take some suitable action, such as to raise the pressure in the cylinder **912** by driving the threaded rod **932** into the second piston **924** with sufficient force to restore stability to the tensioner. In an embodiment, the threaded rod **932** may be driven just into engagement and the motor **940**, preventing the movement of the piston **924** in one direction, thereby preventing the compression of the cylinder **912**.

In an embodiment, the accelerometer **982** may include or may send signals to a math processor or an FFT processor that would determine the amount of movement (i.e. displacement) of the lever arm **936** and/or the frequency of oscillation of the lever arm **936** and/or the acceleration of the lever arm **936**. Such a math or FFT processor could send signals indicative of its determinations to the controller **943**. MEMS chip sensor technologies from companies such as Analog Devices, Honeywell or Sentron could be used in precalibrated sensors and FFT processors similar to those used in some consumer devices such as tablet computers and smartphones.

The accelerometer **982** could also be used in combination with limit switches or some other position sensing technology to assist in the determination of the positions of the components of the tensioner, (i.e. the cylinder **912**, and the lever arm **936**). For example if a limit switch is provided on the lever arm **936**, and if the controller **943** adjusts the pressure in the cylinder **912** when the vehicle is started up so that the lever arm **936** hits the limit switch, the position of the lever arm **936** can be determined thereafter (until the vehicle is turned off), based on data from the accelerometer **982**.

As with the embodiments above, the accelerometer **982** may connect to the controller **943** via a hardwired connection as shown in FIG. **37**, or via a wireless connection.

The accelerometer may be configured to measure acceleration in three axes. The orientation of the three axes may be as shown in FIG. **37**, whereby one of the axes (in the example shown, the x-axis) is generally parallel to the hub load vector when the tensioner arm **936** is in the nominal position when the tensioner **910** is in use on a new belt **911** and the engine is operating in a selected operating condition (e.g. idling). As a result of the match in the orientation of one of the axes of the accelerometer **982** and the hub load vector HLV, the displacement measured by the accelerometer **982** on that axis is approximately directly proportional to the displacement of the pulley **938**. This is simpler than having to calculate an overall displacement based on the vector sums of displacements along a plurality of axes, which is what would occur in embodiments where none of the axes were parallel to the hub load vector. In general having a three axis accelerometer **982** (regardless of which way the axes are oriented) also permits the controller **943** to detect situations wherein there is any displacement in a direction away from the plane in which the tensioner arm moves (i.e. along the z-axis in the embodiment shown in FIG. **37**), or more than a selected amount of displacement along the axis that is in-plane but is generally perpendicular to the hub load vector when the tensioner arm **936** is in the nominal position when the tensioner **910** is in use on a new belt **911** and the engine is operating in a selected operating condition (e.g. idling), (i.e. the y-axis in the exemplary embodiment shown in FIG. **37**). Such a situation can occur when there is wear or damage to one or both of the tensioner arm **936** and the pivot stud **923**.

It would be possible to use the three-axis accelerometer described above, but with the axes in any orientation (i.e. such that none of the axes are aligned with the hub load vector). It would still be possible to obtain all the information that was described above but it would be more processor intensive to obtain it since the controller **943** would determine the movement of the tensioner arm **936** via a vector sum of displacements along two or potentially three axes.

In an alternative embodiment, however, it would be possible to provide an accelerometer **982** with only one axis. Such an accelerometer would be less expensive than a three-axis accelerometer, but would still be capable of providing displacement information regarding the movement of the tensioner arm that would be the same as the information obtained from measuring the x-axis of the three-axis accelerometer with its axes oriented as shown in FIG. **37**.

Use of Position Sensors

Several technologies could be used to provide position data for the components of the tensioner to the controller **943**. As will be understood, providing the position of any one of the first piston **916**, the first and second housings **914/920**, or the lever arm **936** is sufficient for the controller to determine the positions of the other of the components. This information can be used by the controller **943** in combination with the force or pressure information determined above to determine the belt tension. It is alternatively possible to use the position information for other purposes. For example the position information can be used on its own to estimate (roughly) the belt tension. Additionally or alternatively, the position information can be used to detect both the amplitude and frequency of movement of the lever arm **936** during operation of the engine, which the controller **943** can use to detect when the tensioner is unstable, or when there is belt flutter or the like taking place.

An exemplary way of determining the position of the lever arm **936** is to use an absolute rotary position sensor **984** and a dipole magnet **985** that is disk-shaped with one hemi-disk having one polarity and the other hemi-disk having the opposite polarity, as shown in FIGS. **38***a* and **38***b*. The sensor **984** (FIG. **38***b*) may be positioned to sense relative motion between itself and the dipole magnet **985**. The sensor **984** in this embodiment positioned on a mounting bracket **986** that is mounted to the tensioner arm **936** and therefore rotates with the arm **936** about axis ALAP. The dipole magnet **985** may be mounted to the mounting bolt shown at **989**. In the embodiment shown in FIG. **38***b*, the dipole magnet **985** has an extension **987** that is fixedly received in an aperture **988** in the bolt **989**, however it will be understood that the magnet **985** may be mounted to the bolt **989** or to any other suitable stationary base structure in any suitable way. A suitable sensor and magnet for use in this embodiment are shown and described in U.S. Pat. No. 7,188,021. When the tensioner arm **936** rotates, the sensor **984** rotates. This rotation changes the orientation of the sensor **984** relative to the magnet, which is sensed by the sensor **984** and is communicated to the controller **943**. The controller **943** can use this information in combination with the force or pressure information from one of the other sensors described above, to determine the belt tension in belt **911**. Alternatively, the controller **943** could use the sensor information to determine the position of the pulley **938**, which is indicative of the amount of stretch present in the belt **911**. The amount of stretch in the belt **911** can be used to estimate the belt tension in the belt if certain material properties of the belt **911** such as its elastic modulus, are known.

In the embodiment shown in FIG. **38***b*, the sensor **984** rotates through the angular range of the tensioner arm **936**, while the magnet **985** is stationary. It is alternatively possible for the sensor **984** to be mounted stationary (e.g. by way of an extension on the sensor **984** that fits in an aperture **988** in bolt **989**) and for the magnet **985** to rotate with the tensioner arm. The cable leading to the sensor **984** (shown at **979** in FIGS. **38***a* and **38***c*) may be routed so that it clears the bracket **986** so as to not obstruct movement of the tensioner arm **936** (FIG. **38***a*) relative to the cable **991**. Other arrangements for the sensor **984** and magnet **985** may be provided that are similar to the arrangements of sensor and magnet shown in FIGS. **4***a*-**12**.

Instead of determining the angular position of the lever arm **936** for use in determining the belt tension, it would be possible to determine the belt tension using the length of the cylinder **912**. In an alternative embodiment shown in FIG. **39**, a linear position sensor **990** is provided on the cylinder **912** for determining its length. The sensor **990** may be any suitable type of sensor, such as, for example, a linear variable differential transformer (LVDT), such as one that is provided by RDP Electrosense of Pottstown, Pennsylvania, USA. A first portion **991** of the LVDT is connected to the first piston **916** via bracket **993** and the second portion **992** of the LVDT is connected to the first housing **914** via bracket **995**. As the cylinder **912** changes length, the interaction of the first and second portions **991** and **992** changes the voltage output from the LVDT. The LVDT may be connected to the controller **943** so that the controller **943** detects the change in voltage. Determining the length of the cylinder **912** permits the controller **943** to determine the position of the pulley **938** which in turn permits the controller **943** to estimate the belt tension based on the pulley position and the elastic modulus of the belt **911** in addition to numerous other system properties, including, but not limited to: other properties of the belt **911**, of the engine, and of the accessories driven by the belt **911**. Alternatively, it is possible to determine the belt tension using the length of the cylinder **912** (to establish the positions of the cylinder **912** and the lever arm **936**) and the information from one of the force or pressure sensors described above. Another example of a linear sensor that may be suitable for the embodiment shown in FIG. **39** is a magnetorestrictive Temposonics™ sensor provided by MTS Sensors Group of Cary, NC, USA. Another example of a linear sensor that could be employed is a capacitive linear sensor, also referred to as a capacitive linear encoder.

Instead of mounting the linear sensor **990** to the first piston **916** and the first housing **914**, it would alternatively be possible to mount the linear sensor **990** elsewhere on the base structure **917***b* and the lever arm **936** to measure the movement of the lever arm **936**. In such an embodiment, the linear sensor could be fixedly mounted at its first and second ends to first and second portions of a telescoping structure. The first and second portions of the telescoping structure could be pivotally mounted at their distal ends to the base structure **917***b* and to the lever arm **936**. Such an embodiment is shown in FIG. **40**. It will be noted that in the embodiment shown in FIG. **40**, the orientation of the linear sensor is generally parallel to the hub load vector HLV at least in the tensioner arm position shown, which is the nominal position of the tensioner arm **936** when the tensioner **910** is in use on a new belt **911** and the engine is operating in a selected operating condition (e.g. idling). As a result of the match in the orientation of the axis of the sensor **990** and the hub load vector, the displacement measured by the linear position sensor **990** is approximately directly proportional to the displacement of the pulley **938**.

With reference to FIG. **41**, it is possible to use a different type of displacement measurement device then the sensors shown in FIGS. **39** and **40**. For example, a string potentiometer shown at **997** may be used. A string shown at **998** is extendable from a potentiometer body **999** (but is biased to withdraw into the body **999**) and connects to some moving part of the tensioner **910**, such as the tensioner arm **936**. The connection itself may be provided by any suitable structure at the end of the string **998**, such as a simple loop, a carabiner, a magnet, a hook or any other suitable structure. The body **999** is connected to a base structure **917***c*, which may be any suitable base structure. Movement of the tensioner arm **936** causes the string potentiometer **997** to rotate in one direction of the other. The string potentiometer **997** sends signals to the controller **943** indicative of the position of the tensioner arm **936**. Using pulleys at selected positions, the string **998** could be routed through a complex path and so the potentiometer body **999** could be positioned quite remotely from the tensioner arm **936**.

From the point of view of ease of installation, it is preferable to have a tensioner with relatively few components that require individual mounting to their associated base structure. For that reason, embodiments wherein the motor **940** is mounted to the end of the second housing **920** and where the second housing **920** is fixedly connected to the first housing **914** may be advantageous in many applications. In some embodiments, wherein the temperature in proximity to the engine **13** is very high, and/or when the there are extreme levels of vibration that will be incurred by the tensioner (e.g. from torsional vibration from the crankshaft pulley **12**, or from vibration or shaking of the engine **13** itself), it may be advantageous to position the motor **940** away from the rest of the tensioner **910** where it can be thermally isolated from the engine **13** and where it is physically isolated with respect to vibration from the rest of the tensioner **910**. With reference to FIG. **43**, to provide this aforementioned thermal and physical isolation, the second housing **920** may be connected to the first housing **914** via an intermediate conduit shown at **1100** that is flexible. This permits the second housing **920** to be mounted fixedly to a base structure **917***d* and to remain fixed in position there through the range of movement of the cylinder **912**. The intermediate conduit **1100** may be made from any suitable material that is at least somewhat flexible to permit relative movement between the first and second housings **914** and **920**. The intermediate conduit **1100** may have one or more inflexible segments and one or more flexible segments which provide sufficient flexibility to the intermediate conduit **110** that the aforementioned relative movement between the first and second housings **914** and **920** can take place. The inflexible segments may be made from a suitable metal or any other suitable material. The flexible segments may be made from hose or any other suitable material that can provide sufficient flexibility to permit movement of the first housing **914** throughout its range of movement between the load stop position and the free arm stop position. Whatever portions of the intermediate conduit **1100** are flexible may be made from rubber or any other suitable polymeric material. Other examples of suitable material for the conduit **1100** would be a high pressure hydraulic thermoplastic hose.

The intermediate conduit **1100** may be made from a material that flexes in length and/or in diameter when pressurized. In such situations, if steps to prevent such expansion were not taken, the conduit **1100** would have a certain level of spring compliance, damping, and may cause a delay in the response of the system to pressurization, each time the hose is initially pressurized from a rest state. To reduce (and optionally to effectively eliminate) the amount of expansion that the conduit **1100** may include an outermost layer that is a braided steel, braided carbon fibre, or even braided fabric. The amount of elastic compliance available in the conduit **1100** can be selected. Computer modeling or any other suitable means can be used to assist in this process. The flexibility of the conduit **1100** can be selected (specifically, properties such as minimum bending radius, collapsibility, stiffness and other parameters) based on the specific details of the application (e.g. the routing of the conduit, the temperatures it will be exposed to, etc).

The ends of the conduit **1100** may connect to the first and second housings **914** and **920** by any suitable type of connection. For example, the connections may be threaded connections with suitable seals provided. A suitable locking material can be used (e.g. LOKTITE ™) to prevent the conduit **1100** from loosening or separating from the housings **914** and **920**. Alternatively, the ends of the conduit **1100** may be inserted into the housings **914** and **920** and may connect thereto via a threaded compression coupling that incorporates a conical collar that is threaded into position and compresses and locks the conduit **1100** into place. Alternatively, the conduit **1100** may be crimped or staked at their connections to the housings **914** and **920**. In embodiments wherein the conduit **1100** has metallic (e.g. brass) end fittings, the connections may be soldered, brazed or welded, e.g. using laser welding techniques. Such connections could also be used where segments of the conduit **1100** join other segments of the conduit **1100**.

It would be preferable for any stresses that are associated with the flexing of the conduit **1100** to be removed from the connections between the ends of the conduit **1100** and the housings **914** and **920** (and from connections between different segments of the conduit **1100** if there are any). To accomplish this, strain relief structures may be provided across any connection points to inhibit flexing from taking place at the connection points themselves. Such strain relief structures would ensure that substantially all of the flexing in the conduit takes place away from the connection points. A strain relief structure could be a simple rigid member (e.g. a metal bar or sleeve) that is connected at one end to one of the housings **914** or **920** away from the associated connection, and at the other end to the conduit **1100** also away from the associated connection. The rigidity of the strain relief structures thus prevents flexing of the conduit **1100** at the connection. Any other suitable strain relief structures for protecting the connections may alternatively be employed, such as a sleeve made from a non-rigid material such as rubber or some other polymer.

In order to guide which portions of the conduit **1100** flex during operation of the tensioner **910** certain portions of the conduit **1100** may be mounted fixedly to a base structure shown at **917***e*.

The mounting of the second housing **920** (and the motor **940**) may be by simple mounting lugs as shown, without the need for elastomeric vibration isolation members or the like, particularly where the base structure being mounted to is some element such as a portion of the vehicle chassis that is isolated from the engine **13**. If desired, however, isolation members, such as elastomeric members or springs can be provided in the mounting structure of the second housing **920** to help keep the motor **940** isolated from vibration and the like. The mounting structure used for the second housing (and the motor **940** if the motor **940** has any direct contact with the base structure **917***d*) can additionally or alternatively incorporate thermal isolation elements to inhibit the transfer of heat into the motor **940** through the base structure **917***d*.

Several benefits arise from this configuration. As a result of this configuration, the motor **940** can be directly mounted to the second housing **920** for driving the threaded rod **932** (not shown in this figure) without exposing the motor **940** to the movements and vibrations that may be incurred by the cylinder **912** during operation of the tensioner **910** and which could reduce the operating life of the motor **940**. Additionally, because the motor **940** is physically separated from the engine **13**, a thermal barrier shown at **1102** can be provided and positioned between the motor **940** and the engine **13**. This permits the motor **940** to be kept cooler than it might be if it were in closer proximity to the engine **13** as could be the case with embodiments in which it is mounted directly to the end of the second housing **920** and the second housing **920** is fixedly connected to (and proximate to) the first housing **912** as shown in FIGS. **31***a*-**41**. Keeping the motor **940** cooler can increase the operating life of the motor **940** and can reduce the potential for certain kinds of failure such as failure resulting from thermal shock or the like. Additionally or alternatively, keeping the motor **940** cooler permits the use of a less expensive motor **940**. It will be understood that all the advantages described for the motor **940** are applicable to the gearbox **941**. The thermal barrier **1102** is made from a thermally insulative material and thus inhibits the transmission of heat from the engine **13** to the motor **940**. Suitable materials for the thermal barrier **1102** include thin foil sheets which can reflect incoming radiated heat away from the motor **940**. Other suitable materials include, for example, fibrous material with low thermal conductivity. Additionally or alternatively, the thermal barrier **1102** may include a hard shell made from a suitable material having low thermal conductivity. The thermal barrier may be in the form of a wall, as shown, a blanket that fully or partially envelops the motor **940** and optionally the second housing **920**, or a rigid enclosure that fully or partially envelops the motor **940** and optionally the second housing **920**. In embodiments where a blanket or an enclosure is provided, cool air from some source, such as a duct from behind the radiator, shown at **1104**, could be provided to direct cool air to the motor **940**.

To further assist in keeping the temperature of the motor **940** below a selected level, the motor **940** may be positioned behind the vehicle's radiator **1104** and fan (shown at **1106**), as shown in FIG. **43**. Air flow from the radiator **1104** and fan **1106** could thus help to carry heat away from the motor **940**.

A coating may be applied to any metal or polymeric structure to assist in inhibiting the conduction of heat from that structure towards the motor **940**. An example of such a coating is provided by Techline Coatings of Midlothian, Texas, USA under the names CermaKrome™, PolyPhen™ and PowerKote™.

Another technology that could be employed to protect the motor **940** could be in the form of a thermoelectric member as the thermal barrier **1102**. A thermoelectric member, such as that which is provided by Tellurex Corporation of Michigan, USA, is powered electrically to transfer heat from one side (which may be referred to as the cool side), through an array of semiconductor pellets to the other side where the heat is released (which may be referred to as the hot side). The cool side of the thermoelectric member would be the side facing the motor **940**, and the hot side is the side facing away from the motor **940**. Optionally cooling fins could optionally be provided on the hot side. Optionally air flow can be provided through the fins to remove heat therefrom. Air flow to the thermoelectric member can be provided by any suitable means, such as by a fan or by positioning the thermal barrier **1102** in the path of air entering the engine area of the vehicle while the vehicle is being driven. Instead of cooling the hot side by providing an air flow over it, it may be possible to cool the hot side by positioning some other member against the hot side so as to permit heat to be conducted from the hot side into the other member.

Some thermoelectric members are capable of generating electricity from the temperature gradient that exists across them in use. The thermoelectric member could in some embodiments be powered at least in part by the heat coming from the engine **13** itself so as to reduce the cost of its operation.

In some embodiments, it may be possible to apply thermoelectric members in the form of tiles or the like directly to the exterior of the motor **940** (e.g. the motor housing) so as to provide more direct heat transfer from the motor **940** into and through the thermoelectric member. As an alternative, it may be possible to form (e.g. by molding or the like), a single thermoelectric member that is shaped to snugly receive the motor **940** therein thereby providing good heat transfer from multiple faces of the exterior of the motor **940** into and through the thermoelectric member.

While the thermoelectric member has been described above as being used to cool the motor **940** in the embodiment shown in FIGS. **43** wherein the second housing **920** and the motor **940** are remote from the first housing **914**, it is optionally possible for the thermoelectric member to be applied to the motor **940** in the form of tiles or in the form of a single, molded member that at least partially surrounds the motor **940** in embodiments wherein the motor **940** is mounted to the end of the second housing **920** and the second housing is fixedly connected to the first housing **914** as shown, for example in FIGS. **31***a*-**41**.

In an embodiment, the motor **940** itself may be used to determine the position of the pulley **938**. For example, the motor **940** (or some element that is rotated by the motor **940**, such as an element in the gearbox **941**, or the threaded rod **932**) may incorporate a turn counter which may be a magnet and a sensor (i.e. an encoder) that can send a signal to the controller **943** indicative of how many rotations the motor **940** has undergone. If the controller **943** is capable of retaining in memory the true position of the motor **940** after the vehicle is turned off, then the controller **943** is capable of determining the absolute (or true) position of the motor **940** during use. Alternatively if the controller **943** is not capable of retaining in memory the true position of the motor **940** after the vehicle is turned off, then the controller **943** is capable of determining the incremental or relative motor position.

In any embodiment where the position of the tensioner pulley **938** is being used to determine the belt tension, a relationship needs to be determined between pulley position and the belt tension needs to be established during tensioner development. An example of this relationship is shown in the graph **1000** shown in FIG. **42**. The graph **1000** shows tensioner arm angular position vs. belt tension for a particular tensioner configuration.

The tensioner arm angular position is shown in three different scales, all of which are in degrees but which have different zero-points. The vertical line **1002** at 37.5 degrees shows the nominal position of the tensioner arm when the engine **13**, belt **911** and tensioner **910** are manufactured precisely to their specified dimensions and have precisely their specified properties. The vertical line **1004** at 44.8 degrees shows the equivalent position of the tensioner arm when the engine **13** is manufactured at the high end of its tolerance range and the belt **911** is manufactured at the low end of its tolerance range (i.e. long engine, short belt). The vertical line **1006** at 29.8 degrees shows the equivalent position of the tensioner arm when the engine **13** is manufactured at the low end of its tolerance range and the belt **911** is manufactured at the high end of its tolerance range (i.e. short engine, long belt). A curve shown at **1008** represents the relationship of the belt tensioner to the tensioner arm's angular position. Three curves **1008** are shown in FIG. **42**. The curve **1008***b* is the curve that is applicable when the tensioner biasing member **926** is manufactured precisely to its specifications of length and biasing force. The curve **1008***a* is the curve that is applicable when the tensioner biasing member **926** is manufactured to one end of its tolerance range in terms of dimensions and other properties such that it applies a higher biasing force than nominal when the tensioner arm **936** is at any given angle. The curve **1008***c* is applicable when a tensioner biasing member **926** is manufactured at the other end of its tolerance range in terms of dimensions and other properties such that it applies a lower biasing force than nominal when the tensioner arm **936** is at any given angle. Thus, if there is no calibration of the tensioner **910** to determine the particular curve that is applicable, then it can be seen that there is a range of belt tensions that could exist for a given tensioner arm position, due to tolerances in the various components during manufacture. In other words, if there is no calibration, then the belt tension would only be known with a potential error (such as, for example, +/−15% as shown in the graph **1000**) for a given position of the tensioner arm **936**. If there is no calibration of the position sensing device used in the tensioner **910**, the controller may assume that the tensioner arm **936** is at the nominal position when initially installed, and so it will be noted that the position of the tensioner arm **936** will be known with a potential error (such as, for example, about 7.5 degrees).

Calibration of the Tensioner

In an embodiment, the tensioner **910** is capable of calibrating itself upon initial installation in the vehicle (optionally before there is a belt on the engine or before there is any tension in the belt). For example, the controller **943** may drive the motor **940** until the tensioner arm **936** reaches one of its end positions (i.e. its load stop position or its free arm stop position). The controller **943** may detect the tensioner **910** reaching the end position by any suitable means (e.g. by providing limit switches at the end positions, or by monitoring the current to the motor **940** so as to detect when the motor **940** has stalled). Upon determining that the tensioner **910** has reached an end position, the controller **943** may consider this to be a 'home' position. The controller **943** may then drive the motor **940** in the opposite direction until the tensioner **910** reaches the other end position. When moving the tensioner arm **936** to the load-stop position, a suitable tool (not shown) could be attached to the tool receiving feature shown at **1001** and the tool could be used to drive the tensioner arm **936** to its load stop position against the bias of the biasing member **926**. The controller **943** may note the number of rotations of the motor **940** required to reach the other end position, and can thereby tell the position of the tensioner arm **936** at any time by tracking the number of rotations it has carried out in either direction. This is known as a two-point calibration. It is alternatively possible to calibrate the tensioner **910** using one or more other known positions (e.g. using additional limit switches at selected points along the path of motion of the tensioner arm **936**) to further improve the accuracy of the calibration.

The tensioner **910** could alternatively be calibrated using a single point calibration, wherein the tensioner arm **936** is driven by the motor **940** to one end of its travel (e.g. the free-arm stop position). The controller **943** in such an instance would be able to determine the position of the tensioner arm **936** by tracking the number of motor turns that the motor **940** has undergone in each rotational direction, if the angular distance of the tensioner arm per turn of the motor **940** is known. While the turns of the motor **940** are described herein, it will be understood that the controller **943** could track the number of turns of any element that is connected directly or indirectly to the motor **940**, such as the threaded rod **932**, or some element in the gearbox **941**, as noted above. It will be noted that some motors are not capable of recalling their exact position after power-down and would require recalibration upon power-up. Other motors are capable of recalling their exact position even after power-down and subsequent power-up in which case recalibration would not be needed.

With any of the aforementioned types of calibration it is possible to reduce the potential error in the determined position of the tensioner arm **936**. If the tensioner **910** is calibrated in terms of position vs. belt tension during engine or vehicle manufacture, then it would also be possible to reduce the potential error in the determined belt tension based on the determined position.

When the controller **943** determines the belt tension it may do so either by calculation, or more preferably it would do so via a look up table based on the determined position and possibly based on other factors, such as, for example, temperature.

In an embodiment, the controller **943** may be programmed to determine belt tension (at least approximately) from the sensed motor current, since the motor current is, in at least some situations, proportional to the amount of force being exerted by the motor **940**, which is proportional to the amount of force applied by the belt on the pulley **938**, which is proportional to the belt tension. In this embodiment, belt tension could be determined without such elements as the pressure sensor, any load cells or strain gauges or the like. It will be understood that using the motor current may be relatively imprecise as compared to some of the other systems and methods described herein for determining belt tension.

Stall detection on the motor **940** may be beneficial for other purposes than determining when the tensioner has reached an end position. For example, if the controller **943** determines that the motor **940** is stalled when the controller **943** determines that the tensioner has not yet reached an end position, the controller **943** may be programmed to stop the motor **940** to protect the motor **940** from damage and may indicate that there is a problem to the vehicle driver.

In the embodiments described herein, if the controller **943** has brought the tensioner to a high-tension setting, it could return the tensioner to a low-tension setting based on sensor input, or based on other criteria, such as the passage of a pre-determined amount of time.

In the embodiments wherein the vehicle is a hybrid vehicle and the tensioner **910** is used, the MGU **16** may be used in place of an alternator, or alternatively an alternator **16** and a separate motor (not shown) may be used. The MGU **16** will be discussed herein for simplicity, however, it will be understood that in any case where the MGU **16** is described, a motor and a separate alternator could be used.

The MGU **16** may have any one or more of several functions. One function, as described above, is to operate the MGU **16** as a motor and to use it to start the engine **13** (FIG. **1***a*) (which is a function referred to above as a Belt Alternator Start function). Another function would be to use the MGU as a motor to drive selected accessories (e.g. the a/c compressor shown at **18**) when the engine **13** is off (e.g. when the vehicle is stopped at a stoplight), as described above. Yet another function may be for torque smoothing, wherein the MGU **16** is operated in such a way as to cancel out at least some torsional vibration that is exerted on the belt **911** by the crankshaft pulley **12**. In cases where the device **16** is an MGU, it can be used to dynamically cycle the MGU pulley clockwise and counterclockwise in order to phase-match and to hence cancel out a belt drive resonance event, torsional pulley vibration, and/or belt flutter event. Alternatively if the device **16** is an alternator it can still be cycled on and off or between high and low loads to at least partially cancel out one of the aforementioned situations. Such use is described in U.S. Pat. No. 6,998,823, which is incorporated herein by reference. Yet another function for the MGU **16** is for regenerative braking (an alternator could also be used for this purpose). Yet another function is for launch assist, whereby the MGU **16** is operated as a motor and drives the belt **911** while the engine **13** also drives the belt **911**. The MGU **16** thus at least reduces the effort that the engine **13** has to use to drive the accessories, and may itself drive the crankshaft pulley **12** through the belt **911**. In either case, the MGU **16** provides a boost in torque. In some of these situations, such as, for example, when the MGU **16** is being used as a (BAS) Belt Alternator Start device, it may be desirable for the tensioner to increase the belt tension to a high setting to reduce the likelihood of belt slip. The controller **943** may control the input voltage to the motor **940** directly from the on and off signals to the MGU **16** such that when the MGU **16** is operated as a motor, the controller **943** drives the tensioner **910** to the high tensioner setting and when the MGU **16** returns to operation as a generator, the controller **943** brings the tensioner **910** to the low tension setting.

Alternatively, when the MGU **16** is being operated as a motor, the controller **943** may be programmed to keep the belt tension relatively low to help reduce the parasitic losses incurred when it is used to drive any accessories. When it is to be used to start the engine **13**, the MGU **16** can be used first to drive up the belt tension, so that when the MGU **16** is driven to start rotation of the crankshaft pulley **12**, belt slip is unlikely to occur. It will be noted that when the engine **13** is stopped, the amount of resistance of the crankshaft pulley **12** is quite high, and as a result the torque required to drive the crankshaft pulley **12** can be relatively high. In order to describe the driving up of the belt tension, the belt spans are identified in FIG. **15**. The belt spans are shown at S**1** to S**5**. It will be noted that, during normal operation of the engine **13** (FIG. **1**) the crankshaft pulley **12** is driving the belt **911** and is rotating clockwise in the view shown in FIG. **15**. The belt span S**1** may be referred to as the belt span leaving the crankshaft pulley **12**. The belt span S**2** may be referred to as the belt span leaving the accessory pulley **915** (e.g. water pump pulley **915**), or may be referred to as the belt span leading to the tensioner pulley **938**. The belt span S**3** may be referred to as the belt span leaving the tensioner pulley **938** or may be referred to as the belt span leading to the pulley **60** for the MGU **16** or for the alternator **16**. The belt span S**4** may be referred to as the belt span leaving the alternator **16** or may be referred to as the belt span leading to the a/c compressor pulley **60**. The belt span S**5** may be referred to as the belt span leading to the crankshaft pulley **12**.

When the crankshaft is driving the belt **911** the spans S**4** and S**5** may be considered to be tight and the spans S**1**, S**2** and S**3** may be considered relatively slack (compared to spans S**4** and S**5**). However, when the MGU **16** is operated as a motor, belt spans S**4** and S**5** are slack and spans S**1**, S**2** and S**3** are relatively tight. In order to drive up the belt tension, the MGU **16** may be driven briefly in a direction (counterclockwise in the view shown in FIG. **15**) opposite to its normal direction of rotation. This increases the tension in the belt spans S**4** and S**5** and drives slackness in the belt **911** into the spans S**3** and S**2**. As soon as the belt spans S**2** and S**3** slacken the tensioner biasing member **926** drives the tensioner pulley **938** into the belt **911** to take up the slack. To ensure that the tensioner **910** holds the belt at the level of tension that it has at that moment, the motor **940** is commanded by the controller **943** to drive the threaded rod **932** up to the floating piston **924** so that it abuts it, thereby preventing the cylinder **912** from expanding and preventing the belt **911** from pulling the tensioner pulley **938** during normal (clockwise in the figure) rotation of the MGU **16**. Once the rod **932** is abutted with the floating piston **924**, the MGU **16** can be driven in the clockwise direction briefly to build slack into the belt spans S**4** and S**5**. The MGU **16** can then be driven again in the counterclockwise direction to try to bring this slack from spans S**4** and S**5** into the spans S**2** and S**3**, where again the slack will be taken up by movement of the tensioner pulley **938** under the bias of the biasing member **926**. This movement of the pulley **938** will be accompanied by an extension of the cylinder **912** and consequent movement of the floating piston **924** away slightly from the end of the threaded rod **932**. Again the threaded rod **932** will be driven back into abutment with the floating piston **924**, locking the piston **924** and therefore preventing the belt **911** from pulling the pulley **938** in the load stop direction (i.e. clockwise in FIG. **15**). This reciprocation of the MGU **16** can continue for a selected number of cycles, or for a selected period of time or until a selected belt tension is reached. Once this is completed, the belt **911** is ready to be used to drive the crankshaft pulley **12** to start the engine **13**. In a preferred embodiment, this cycling of the MGU can take place as soon as or shorter after the engine **13** is shut off as the vehicle is coming to a stop (e.g. at a stoplight or at a stop sign). As a result, the vehicle is ready to start up the engine **13** as soon as the driver indicates to the vehicle that he/she wants it. By readying the belt **911** to start up the engine **13** relatively quickly after shutting down the engine during a stop, can be valuable in the event that the driver needs to accelerate away quickly, such as in an emergency situation in which the driver needs to avoid a collision from another vehicle. In an alternative embodiment, the belt tension may be kept relatively low for a period while the vehicle is stopped to reduce the amount of energy that is expended by the MGU **16** to drive the accessories such as the a/c compressor **18** while the vehicle is stopped at a stoplight and the engine **13** is off. At some point, such as when the driver depresses the accelerator pedal to pull away from the stoplight, the MGU **16** can be cycled back and forth as indicated above so as to drive up the belt tension. The cycling of the MGU **16** back and forth as indicated above may be referred to as 'feathering'. The belt tension achieved during this process may be as high as 2000 N, or even higher for a brief moment when the MGU **16** is driving the crankshaft pulley **12**.

When driving the belt tension up to high levels, such as when feathering the MGU to prepare the belt **911** for driving the crankshaft pulley **12**, it may be preferable to use load sensing or pressure sensing devices instead of position sensing devices, since load sensing devices are a relatively more direct means of determining the belt tension and are, in that sense, a more accurate means of determining belt tension. In general when driving the tension in the belt up to high levels, it is beneficial for the controller **943** to be aware of the loads in the tensioner **910** particularly in embodiments where there is no spring compliance (such as the biasing member **928** shown in the embodiment in FIG. **26**, or such as the use of a conduit that is elastically expandable in the embodiment shown in FIG. **43**). Without spring compliance, very small linear movement of the threaded rod **932** into the second piston **924** could cause very large changes in belt tension and in the loads that are applied to pulleys and the like in the tensioner **910** and in the accessory drive system in general. As a result, when driving up the belt tension, the movement of the threaded rod **932** is preferably precisely controlled and is controlled with good feedback on the loads in the tensioner **910** in order to inhibit damage to tensioner and accessory drive components.

For greater certainty, it will be understood that in at least some embodiments, and even some embodiments wherein the vehicle is a hybrid vehicle, the device **16** may be an alternator instead of an MGU.

While the term 'belt' has been used in the description herein, it will be understood that the tensioning system of the present invention can apply to many different kinds of endless drive element, both synchronous (e.g. toothed) and asynchronous (e.g. non-toothed), including accessory drive belts, timing belts, timing chains and the like.

In the embodiments shown in FIGS. **15-43**, it will be noted that the particular arrangement of the hydraulic actuator **913**, the tensioner arm **936**, the pulley **938** could be different for different applications, while still using some means (such as the motor **940** and the threaded rod **932**) for selectively preventing or limiting the compression of the cylinder **912** by preventing movement in a selected direction of the floating piston **924**, and/or while still using some means (such as the motor **940** and the threaded rod **932**) for driving the cylinder **912** to extend thereby driving the pulley **938** into the belt **911** to increase the belt tension.

In the embodiments shown in FIGS. **1-14***b* sensors and the like are described for detecting certain properties and conditions. Additionally, several control schemes are described based on several conditions and signals from the described sensors. For greater certainty, it will be noted that the control schemes and the sensors described in relation to the embodiments shown in FIGS. **1-14***b* are applicable to the embodiments shown in FIGS. **15-43**.

For greater certainty, anywhere in this disclosure where a belt is described or shown, the belt may alternatively be any endless drive member, whether synchronous (e.g. toothed) or asynchronous (non-toothed).

While the description contained herein constitutes a plurality of embodiments of the present invention, it will be appreciated that the present invention is susceptible to further modification and change without departing from the fair meaning of the accompanying claims.

The invention claimed is:

1. A tensioning system for tensioning an endless drive member, comprising:

a tensioner pulley that is movable between a free arm stop position and a load stop position;

a tensioner arm which supports the tensioner pulley;

a tensioner actuator that includes a fluid actuated cylinder positioned to exert a force on the tensioner arm to drive the tensioner pulley towards the free arm stop position;

a tensioner biasing member positioned to bias the tensioner pulley towards the free arm stop position; and

a motor that is operatively connected to the fluid actuated cylinder to control the force exerted by the fluid actuated cylinder on the tensioner arm,

wherein the tensioner actuator acts in parallel with the tensioner biasing member.

2. A tensioning system as claimed in claim **1**, further comprising:

a controller operatively connected to the motor to control the tensioning force, wherein the controller is configured to receive signals indicative of the state of at least one vehicle component aside from the tensioning system, wherein the state of the at least one vehicle component impacts the likelihood of slip of the endless drive member, wherein the controller is programmed to:

a) determine whether or not the state of the at least one vehicle component is cycling between first and second states with a cycle time that is less than a selected cycle time, wherein in the first state there is a relatively greater likelihood of slip, and in the second state there is a relatively smaller likelihood of slip, and

b) control the tensioning force so to control the tension in the endless drive member based at least in part on the determination in step a).

3. A tensioning system as claimed in claim **2**, further comprising at least one sensor configured to send signals to the controller indicative of a condition of the tensioning system and indicative of the tension in the endless drive member.

4. A tensioning system as claimed in claim **3**, wherein the at least one sensor includes a pressure sensor positioned to determine the fluid pressure in the fluid actuated cylinder.

5. A tensioning system as claimed in claim **2**, wherein the controller is programmed to provide a relatively high tensioning force if the determination made in step a) is that the at least one vehicle component is cycling, and wherein the controller is programmed in at least one other circumstance to provide a relatively low tensioning force if the determination made in step a) is that the at least one vehicle component is not cycling.

6. A tensioning system as claimed in claim **2**, wherein the at least one vehicle component is the engine and the first state corresponds to high rpm of the engine, and the second state corresponds to low rpm of the engine.

7. A tensioning system as claimed in claim **2**, wherein the at least one vehicle component is the engine and the first state corresponds to a high rate of change in the rpm of the engine, and the second state corresponds to a low rate of change in the rpm of the engine.

8. A tensioning system as claimed in claim **1**, wherein the controller is programmed to:

issue commands for controlling the operation of at least one vehicle accessory so as to control the tension in the endless drive member; and

control the tensioning force so to control the tension in the endless drive member based at least in part on the issued commands.

9. A tensioning system as claimed in claim **8**, wherein the vehicle includes a vehicle control unit that is operatively connected to the at least one vehicle accessory, and wherein the controller is programmed to issue the commands for controlling the operation of the at least one vehicle accessory to the vehicle control unit, and is further programmed to determine whether the vehicle control unit will execute the commands or not.

10. A tensioning system as claimed in claim **8**, wherein the at least one vehicle accessory includes an alternator and wherein the controller is configured to receive signals indicative of the speed of the alternator, the temperature of the alternator and the voltage output of the alternator, and wherein the controller is programmed to control the operation of the alternator based on the level of charge in a vehicle battery that is charged by the alternator, and based on the tension in the endless drive member.

11. A tensioning system as claimed in claim **8**, wherein the at least one vehicle accessory includes a first vehicle accessory and a second vehicle accessory, wherein the controller is further programmed to:

control the tension in the endless drive member by preventing full operation of the first vehicle accessory and permit the operation of the second vehicle accessory when the controller determines that operation of the second vehicle accessory is needed and that full operation of the first vehicle accessory is not needed; and

control the tension in the endless drive member by preventing full operation of the second vehicle accessory and permit the operation of the first vehicle accessory when the controller determines that operation of the first vehicle accessory is needed and that full operation of the second vehicle accessory is not needed.

12. A tensioning system as claimed in claim **11**, wherein the controller is further programmed to:

control the tensioning force exerted by the tensioner pulley to increase tension when the controller determines that full operation of both the first vehicle accessory and the second vehicle accessory is needed.

13. A tensioning system as claimed in claim **8**, wherein the controller is configured to receive signals indicative of the speed of the tensioner pulley and the speed of at the at least one vehicle accessory, and is programmed to:

determine the amount of slip that exists between the endless drive member and the at least one vehicle accessory based on the speed of the tensioner pulley and the speed of the at least one accessory; and

control the tensioning force to control the amount of slip.

14. A tensioning system as claimed in claim **8**, wherein the tensioner includes:

a pivot shaft that is fixedly mountable with respect to an engine block of an engine in the vehicle;

a tensioner arm rotatably mounted to the pivot shaft for pivoting about a tensioner arm axis between the free arm stop position and the load stop position, wherein the pulley is rotatably mounted to the tensioner arm; and

a tensioner spring positioned to exert a biasing force on the tensioner arm to bias the tensioner arm towards the free arm stop position, wherein the tensioner spring has a first end and a second end, wherein the first end is engaged with the tensioner arm.

15. A tensioning system as claimed in claim **8**, wherein the vehicle includes a vehicle control unit that is operatively connected to the at least one vehicle accessory, and wherein the controller is programmed to issue the commands for controlling the operation of the at least one vehicle accessory directly to the at least one vehicle accessory, and wherein operation of the at least one accessory under the control of the controller requires permission by the vehicle control unit.

16. A tensioning system as claimed in claim **1**, wherein the vehicle includes an engine, a vehicle control unit that shuts off the engine temporarily at selected moments, and an electric motor positioned to drive the endless drive member when the engine is off, and wherein the controller is programmed to:

a) determine whether or not the engine has been turned off temporarily by the vehicle control unit, and

b) provide a low tensioning force to control the force required by the electric motor to drive the endless drive member based on the determination.

17. A tensioning system as claimed in claim **16**, wherein the controller is programmed to reduce the tensioning force based on the determination.

18. A tensioning system as claimed in claim **16**, wherein the vehicle control unit is programmed to start the engine by driving the endless drive member with the electric motor, wherein the engine has a crankshaft and a crankshaft pulley on the crankshaft, wherein the crankshaft pulley is engaged with the endless drive member and drives the endless drive member when the engine is on, wherein the electric motor has a first side which is a lower tension side when the electric motor is driving the endless drive member, and a second side which is a higher tension side when the electric motor is driving the endless drive member, wherein the crankshaft pulley is positioned on the first side of the electric motor, and wherein the controller is programmed to:

determine whether or not the vehicle control unit is about to drive the electric motor to start the engine, and

provide a high tensioning force based on the determination so as to control the tension in the endless drive member on the second side of the crankshaft pulley when the electric motor is used to start the engine.

19. A tensioning system as claimed in claim **16**, wherein the electric motor is an alternator when the crankshaft pulley drives the endless drive member.

20. A tensioning system for tensioning an endless drive member, comprising:

a tensioner pulley that is movable between a free arm stop position and a load stop position;

a tensioner arm which supports the tensioner pulley;

a tensioner actuator operatively connected to the tensioner arm and including a fluid actuated cylinder that is controllable to adjust a force exerted on the tensioner arm so as to control a force exerted by the tensioner pulley on the endless drive member; and

a tensioner biasing member positioned to bias the tensioner pulley towards the free arm stop position;

wherein the tensioner actuator acts in parallel with the tensioner biasing member.

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